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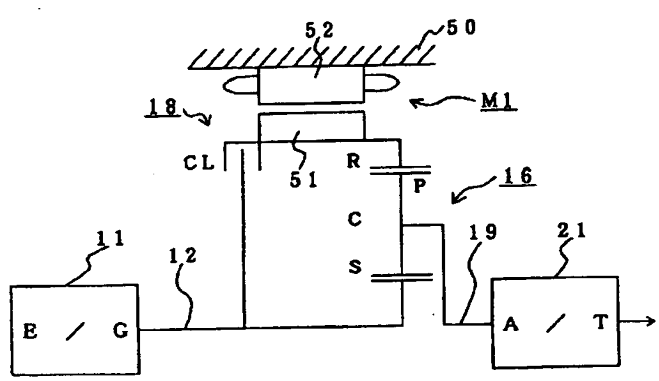
(54) Starting system with energy recovery for automotive vehicles

(57) A starting system for a vehicle which during starting can effect smooth starting and furthermore can convert into electrical energy and store in a battery excess kinetic energy accompanying the difference in speed between the engine and the driving wheels occurring during starting comprises: a gearbox (18), having at least a first gear element (5) connected to an output shaft (12) of an engine (11), a second gear element (P) connected to a driving wheel of a vehicle and a third gear element (R) connected to an electric rotary device (51,52); an accumulator; engine load detecting means for detecting an engine load; speed detecting means for detecting the speed of at least one of the gear elements of the gearbox and outputting a speed signal; and a control unit.

Each time the vehicle starts moving, excess kinetic energy is converted into electrical energy by the electric rotary device and can be stored in a battery and used to run electrical equipment of the vehicle or auxiliary equipment of the engine or to drive the electric rotary device. As a result, fuel consumption can be improved.

FIG. 3



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Description

This invention relates to a starting system.

Conventionally, in an engine (for example an internal combustion engine) mounted in a vehicle, because when the engine speed falls below a certain speed the engine cannot produce any torque, to start the vehicle moving torque is transmitted to the driving wheels with the engine being run at a predetermined speed. However, when the vehicle is stationary, the speed of the driving wheels is 0 and there is a difference in speed between the engine and the driving wheels.

For this reason, a starting unit such as a frictional clutch or a fluid clutch is interposed between the engine and the driving wheels and torque is transmitted with the above-mentioned speed difference being allowed.

Taking as an example a case where a torque convertor is used as the fluid clutch, even when a neutral range has been selected by a driver and the engine has been disconnected from the driving wheels and the vehicle has stopped, the engine is run at an idling speed.

Consequently, when to start the vehicle moving a forward range such as a D range is selected and a clutch for forward movement is engaged and the engine and the driving wheels are connected by the torque convertor, whereas the input side of the torque convertor is rotated at an idling speed the output side of the torque convertor is kept substantially stationary by the inertia of the vehicle.

When the driver then depresses an accelerator pedal the engine speed gradually increases and the torque convertor transmits torque to the driving wheels and starts the vehicle moving while slipping corresponding to the input-output speed difference occurs in a hydraulic fluid inside the torque convertor.

When after the vehicle has started moving the vehicle speed (the speed of the driving wheels) reaches a speed at which the engine speed can be kept at a predetermined speed without there being an input-output speed difference in the torque convertor, the input and output sides of the torque convertor are directly coupled by a lock-up clutch or the like and the speed difference is eliminated.

However, in the conventional starting system described above, while the vehicle is starting to move, because torque is transmitted with an input-output speed difference being allowed by slipping of the hydraulic fluid in the case of a torque convertor and slipping of friction surfaces in the case of a frictional clutch, excess kinetic energy accompanying the occurrence of the input-output speed difference is converted into heat and dissipated. As a result, the kinetic energy produced by the engine cannot be used effectively.

An object of this invention is to solve the above-mentioned problem associated with conventional starting systems and provide a starting system which during starting can effect smooth starting by transmitting torque produced by an engine to driving wheels while allowing an input-output speed difference and which when the vehicle has started moving can transmit torque produced by the engine to the driving wheels without allowing an input-output speed difference and furthermore can convert into electrical energy and store excess kinetic energy accompanying the occurrence of the input-output speed difference.

To achieve this object and other objects, a starting system of the invention comprises: a gearbox, having at least a first gear element connected to an output shaft of an engine, a second gear element connected to a driving wheel of a vehicle and a third gear element, for by applying a braking torque to the third gear element reducing the speed of a rotation inputted from the first gear element and outputting it to the second gear element; an engaging element connected to any of the gear elements for being selectively engaged and mechanically connecting the output shaft of the engine to the driving wheel; an electric rotary device connected to the third gear element; an accumulator; engine load detecting means for detecting an engine load; speed detecting means for detecting the speed of at least one of the gear elements of the gearbox and outputting a speed signal; and a control unit.

The control unit comprises electric rotary device controlling means for setting a target speed of the first gear element based on the engine load and bringing the speed of the first gear element obtained from the speed signal to the target speed by driving the electric rotary device and causing the electric rotary device to generate a braking torque and engaging element engaging and disengaging means for comparing the speed of a gear element other than the first gear element obtained from the speed signal with set values for engaging and disengaging and engaging and disengaging the engaging element based on the comparison results.

In another starting system of the invention, the set values for engaging and disengaging are set in correspondence with the engine load and are higher the greater the engine load is.

In another starting system of the invention there are provided operating means for selecting a driving state and a non-driving state of the vehicle and vehicle speed detecting means for detecting the speed of the vehicle.

Also, the electric rotary device controlling means is provided with braking torque setting up means for driving the electric rotary device and setting up a braking torque when a driving state of the vehicle is selected by means of the operating means and the engine load detected by the engine load detecting means is substantially zero and the vehicle speed detected by the vehicle speed detecting means is below a set value.

In another starting system of the invention there are provided brake detecting means for detecting depression of a brake pedal and vehicle speed detecting means for detecting the speed of the vehicle.

Also, the electric rotary device controlling means makes the braking torque generated by the electric rotary device zero when depression of the brake pedal is detected by the brake detecting means, the engine load detected by the engine load detecting means is substantially zero and the vehicle speed detected by the vehicle speed detecting means is below a set value.

In another starting system of the invention, when the engine load detected by the engine load detecting means is substantially zero and the speed of a gear element other than the first gear element obtained from the speed signal is below a set value for release, the engaging element engaging and disengaging means releases the engaging element and the electric rotary device controlling means keeps the speed of a gear element other than the first gear element obtained from the speed signal in a high electricity generation efficiency region.

In another starting system of the invention, when the engine load detected by the engine load detecting means is substantially zero and the speed of a gear element other than the first gear element obtained from the speed signal is below a set value for release, the engaging element engaging and disengaging means releases the engaging element and the electric rotary device controlling means keeps the speed of the first gear element obtained from the speed signal above a set value.

In another starting system of the invention there is provided a remaining charge detecting device for monitoring the charge state of the accumulator.

Also, when the engine load detected by the engine load detecting means is substantially zero and the speed of a gear element other than the first gear element obtained from the speed signal is below a first set value for release and the charge state of the accumulator monitored by the remaining charge detecting device is poor the engaging element engaging and disengaging means releases the engaging element and the electric rotary device controlling means keeps the speed of a gear element other than the first gear element obtained from the speed signal in a high electricity generation efficiency region.

Also, when the engine load detected by the engine load detecting means is substantially zero and the speed of a gear element other than the first gear element obtained from the speed signal is below a second set value for release and the charge state of the accumulator monitored by the remaining charge detecting device is good the engaging element engaging and disengaging means releases the engaging element and the electric rotary device controlling means keeps the speed of the first gear element obtained from the speed signal above a set value.

In another starting system of the invention there is provided calculating means for calculating a speed difference or a speed ratio of speeds of two gear elements detected by the speed detecting means.

Also, when the speed of a gear element other than the first gear element obtained from the speed signal is above a set value for engaging and the speed difference or speed ratio calculated by the calculating means is smaller than a preset deviation constant, the engaging element engaging and disengaging means engages the engaging element.

In another starting system of the invention the deviation constant is set in correspondence with the engine load and is larger the larger the engine load is.

In another starting system of the invention there is provided a remaining charge detecting device for monitoring the charge state of the accumulator.

Also, the electric rotary device is a generator/motor and the preset deviation constant is set to a small value when the charge state monitored by the remaining charge detecting device is good and to a large value when the charge state is poor. In another starting system of the invention, when the speed of a gear element other than the first gear element obtained from the speed signal is above a set value for engaging and the absolute value of the speed of a gear element other than the first gear element obtained from the speed signal is substantially zero, the engaging element engaging and disengaging means engages the engaging element.

In another starting system of the invention, when the speed of a gear element other than the first gear element obtained from the speed signal is above a set value for engaging and the absolute value of the speed of a gear element other than the first gear element obtained from the speed signal is smaller than a set value set in correspondence with the engine load the engaging element engaging and disengaging means engages the engaging element.

In another starting system of the invention there is provided regenerated power detecting means for detecting a regenerated power generated by the electric rotary device.

Also, when the speed of a gear element other than the first gear element obtained from the speed signal is above a set value for engaging and the regenerated power detected by the regenerated power detecting means is smaller than a set value the engaging element engaging and disengaging means engages the engaging element.

In another starting system of the invention the electric rotary device is a generator.

In another starting system of the invention the electric rotary device is a generator/motor.

In another starting system of the invention, when engaging of the engaging element by the engaging element engaging and disengaging means has been completed the electric rotary device controlling means reduces a braking torque generated by the generator/motor by a set rate.

In another starting system of the invention, from the start of engaging of the engaging element by the engaging element engaging and disengaging means to the completion thereof the electric rotary device controlling means reduces the braking torque of the generator/motor.

In another starting system of the invention there is provided a one-way clutch for transmitting a rotation of the generator/motor to the output shaft of the engine.

In another starting system of the invention the engaging element is a clutch of normally closed type and transmits a rotation of the generator/motor to the output shaft of the engine.

In another starting system of the invention, when the difference between a power obtained from regeneration by the generator/motor and a power consumed in driving the generator/motor is smaller than a set value and the speed of a gear element other than the first gear element obtained from the speed signal is larger than a set value for disengaging the engaging element engaging and disengaging means engages the engaging element.

Another starting system of the invention comprises: a gearbox, having at least a first gear element connected to an output shaft of an engine, a second gear element connected to a driving wheel of a vehicle and a third gear element, for by applying a braking torque to the third gear element reducing the speed of a rotation inputted from the first gear element and outputting it to the second gear element; an engaging element connected to any of the gear elements for being selectively engaged and mechanically connecting the output shaft of the engine to the driving wheel; an electric rotary device connected to the third gear element; an accumulator; engine load detecting means for detecting an engine load; speed detecting means for detecting the speed of at least one of the gear elements of the gearbox and outputting a speed signal; and a control unit.

Also, the control unit comprises electric rotary device controlling means for setting a target speed of the first gear element based on the engine load and bringing the speed of the first gear element obtained from the speed signal to a target speed by driving the electric rotary device and causing the electric rotary device to generate a braking torque and engaging element engaging and disengaging means for comparing the speed of the first gear element when the engaging element has been engaged with a set value for disengaging and disengaging the engaging element based on the comparison results.

As described above, a starting system according to the invention comprises: a gearbox, having at least a first gear element connected to an output shaft of an engine, a second gear element connected to a driving wheel of a vehicle and a third gear element, for by applying a braking torque to the third gear element reducing the speed of a rotation inputted from the first gear element and outputting it to the second gear element; an engaging element connected to any of the gear elements for being selectively engaged and mechanically connecting the output shaft of the engine to the driving wheel; an electric rotary device connected to the third gear element; an accumulator; engine load detecting means for detecting an engine load; speed detecting means for detecting the speed of at least one of the gear elements of the gearbox and outputting a speed signal; and a control unit.

The control unit comprises electric rotary device controlling means for setting a target speed of the first gear element based on the engine load and bringing the speed of the first gear element obtained from the speed signal to the target speed by driving the electric rotary device and causing the electric rotary device to generate a braking torque and engaging element engaging and disengaging means for comparing the speed of a gear element other than the first gear element obtained from the speed signal with set values for engaging and disengaging and engaging and disengaging the engaging element based on the comparison results.

In this case, in a starting system of this construction, when the vehicle is stationary, normally a neutral range is selected, the throttle opening is set to an idling throttle opening and the engine is rotated at an idling speed. At this time, the rotation of the engine is transmitted to the gearbox by the engine output shaft and the first gear element is rotated at the idling speed.

Next, when to start the vehicle moving a driver selects a D range and increases the engine load, the electric rotary device controlling means sets a target speed of the first gear element based on the engine load and drives the electric rotary device and thereby generates a torque so that the speed of the first gear element approaches the target speed.

At this time, rotation at the target speed is transmitted to the first gear element, but because the inertia of the vehicle is transmitted to the second gear element and the speed of the second gear element consequently is 0 the electric rotary device is rotated as a load. As a result, the electric rotary device operates as a generator and exerts a braking torque while generating a regeneration current.

Because along with the production of the braking torque a torque equal to the sum of the engine torque and the braking torque is transmitted to the driving wheels, the vehicle starts to accelerate and the speed of the second gear element also gradually increases.

Thereafter, when the speed of the second gear element rises above a set value for engagement, the engaging element is engaged.

In this way, when the gearbox becomes mechanically coupled, the rotation of the output shaft of the engine is transmitted to the driving wheels unchanged or converted by a predetermined gear ratio.

As a result, every time the vehicle starts moving, excess kinetic energy of the kinetic energy produced by the engine is used to rotate the third gear element braked by the braking torque as a load and is converted into electrical energy by the electric rotary device. Current thus produced by the electric rotary device in a regenerating state can be stored in an accumulator. Electrical energy thus stored can be used to run electrical equipment of the vehicle or auxiliary equipment of the engine or to drive the electric rotary device. As a result, fuel consumption can be improved.

Also, although when the starting system is provided with a transmission between the gearbox and the driving wheels a gear-change shock caused by inertia torque occurs on gear-changing in the transmission, by temporarily putting the starting system into the regenerating state during the gear-changing transient state the torque inputted into the gearbox can be reduced and gear-change shock can thereby be prevented.

Because the engaging element is engaged when the speed of the second gear element exceeds a set value for engaging, not only can engine stalling be prevented but also the kinetic energy produced by the engine can be directly transmitted to the driving wheels without any of it being converted into electrical energy and therefore fuel consumption can be improved.

Also, it is possible to make the gearbox and the engaging element have the function of an auxiliary transmission. That is, if an open ratio transmission is used as a main transmission and a gearbox with relatively small gear ratios and an engaging element are used as an auxiliary transmission, a cross-ratio multistage automatic transmission is obtained. In this case, the engaging element can be changed over between its engaged state and its released state in each gear of the main transmission.

In another starting system of the invention, the set values for engaging and disengaging are set in correspondence with the engine load and are made higher the greater the engine load is. As a result, when in such cases as when a demand for acceleration is high the engine load becomes high, the engaging element is engaged slowly and released quickly.

In another starting system of the invention there are provided operating means for selecting a driving state and a non-driving state of the vehicle and vehicle speed detecting means for detecting the speed of the vehicle.

Also, the electric rotary device controlling means is provided with braking torque setting up means for driving the electric rotary device and setting up a braking torque when a driving state of the vehicle is selected by means of the operating means and the engine load detected by the engine load detecting means is substantially zero and the vehicle speed detected by the vehicle speed detecting means is below a set value.

In this case, by the braking torque produced by the electric rotary device being increased, the torque outputted to the driving wheels can be swept up and made into a creep torque.

In another starting system of the invention there are provided brake detecting means for detecting depression of a brake pedal and vehicle speed detecting means for detecting the speed of the vehicle.

Also, the electric rotary device controlling means makes the braking torque generated by the electric rotary device zero when depression of the brake pedal is detected by the brake detecting means, the engine load detected by the engine load detecting means is substantially zero and the vehicle speed detected by the vehicle speed detecting means is below a set value.

As a result, when the driver has depressed the brake pedal, a neutral state can be created.

In another starting system of the invention, when the engine load detected by the engine load detecting means is substantially zero and the speed of a gear element other than the first gear element obtained from the speed signal is below a set value for release, the engaging element engaging and disengaging means releases the engaging element and the electric rotary device controlling means keeps the speed of a gear element other than the first gear element obtained from the speed signal in a high electricity generation efficiency region.

As a result, during coasting, by releasing the engaging element and driving the electric rotary device in a high electricity generation efficiency region, the amount of electrical energy regenerated by the electric rotary device can be made large.

In another starting system of the invention, when the engine load detected by the engine load detecting means is substantially zero and the speed of a gear element other than the first gear element obtained from the speed signal is below a set value for release, the engaging element engaging and disengaging means releases the engaging element and the electric rotary device controlling means keeps the speed of the first gear element obtained from the speed signal above a set value.

As a result, during coasting, by releasing the engaging element and increasing the engine speed and continuing with a fuel cutoff, fuel consumption can be improved.

In another starting system of the invention there is provided a remaining charge detecting device for monitoring the charge state of the accumulator.

Also, when the engine load detected by the engine load detecting means is substantially zero and the speed of a gear element other than the first gear element obtained from the speed signal is below a first set value for release and the charge state of the accumulator monitored by the remaining charge detecting device is poor the engaging element engaging and disengaging means releases the engaging element and the electric rotary device controlling means keeps the speed of a gear element other than the first gear element obtained from the speed signal in a high electricity generation efficiency region.

Also, when the engine load detected by the engine load detecting means is substantially zero and the speed of a gear element other than the first gear element obtained from the speed signal is below a second set value for release and the charge state of the accumulator monitored by the remaining charge detecting device is good the engaging

element engaging and disengaging means releases the engaging element and the electric rotary device controlling means keeps the speed of the first gear element obtained from the speed signal above a set value.

As a result, during coasting, when the charge state of the accumulator is good, by releasing the engaging element and increasing the engine speed and continuing with a fuel cutoff, fuel consumption can be improved.

When the charge state of the accumulator is poor, by releasing the engaging element and driving the electric rotary device in a high electricity generation efficiency region, the amount of electrical energy regenerated by the electric rotary device can be made large.

In another starting system of the invention there is provided calculating means for calculating a speed difference or a speed ratio of speeds of two gear elements detected by the speed detecting means.

Also, when the speed of a gear element other than the first gear element obtained from the speed signal is above a set value for engaging and the speed difference or speed ratio calculated by the calculating means is smaller than a preset deviation constant, the engaging element engaging and disengaging means engages the engaging element.

In this case, because it is possible to engage the engaging element when two speeds among the speed of the first gear element, the speed of the second gear element and the speed of a gear element other than the first gear element are the same, engaging shock can be reduced.

In another starting system of the invention the deviation constant is set in correspondence with the engine load and is larger the larger the engine load is. As a result, when the engine load is large, engine stalling will not occur even when the engaging element is engaged. Accordingly the direct coupling clutch is engaged quickly and released slowly.

In another starting system of the invention there is provided a remaining charge detecting device for monitoring the charge state of the accumulator.

Also, the electric rotary device is a generator/motor and the preset deviation constant is set to a small value when the charge state monitored by the remaining charge detecting device is good and to a large value when the charge state is poor. As a result, because when the charge state of the accumulator is good the engaging element is released when the speed difference or speed ratio has become small, engaging shock can be suppressed. When the charge state of the accumulator is poor, the amount of electrical energy consumed by the electric rotary device can be reduced.

In another starting system of the invention, when the speed of a gear element other than the first gear element obtained from the speed signal is above a set value for engaging and the absolute value of the speed of a gear element other than the first gear element obtained from the speed signal is substantially zero, the engaging element engaging and disengaging means engages the engaging element.

As a result, a generator can be used as the electric rotary device. In this case, because only a regenerating state is created and no driving state is created, the output control unit can be simplified.

In another starting system of the invention, when the speed of a gear element other than the first gear element obtained from the speed signal is above a set value for engaging and the absolute value of the speed of a gear element other than the first gear element obtained from the speed signal is smaller than a set value set in correspondence with the engine load the engaging element engaging and disengaging means engages the engaging element.

In this case, it is possible to use a separately excited generator in which permanent magnets are not used as the electric rotary device.

In another starting system of the invention there is provided regenerated power detecting means for detecting a regenerated power generated by the electric rotary device.

Also, when the speed of a gear element other than the first gear element obtained from the speed signal is above a set value for engaging and the regenerated power detected by the regenerated power detecting means is smaller than a set value the engaging element engaging and disengaging means engages the engaging element.

In this case, when as the vehicle speed increases with the target speed maintained unchanged the speed of a gear element other than the first gear element increases and the regenerated power becomes substantially zero, the engaging element is engaged.

In another starting system of the invention the electric rotary device is a generator.

In this case, because only a regenerating state is created and no driving state is created, the output control unit can be simplified.

In another starting system of the invention the electric rotary device is a generator/motor.

In this case, a regenerating state and a driving state can be created using the generator/motor.

In another starting system of the invention, when engaging of the engaging element by the engaging element engaging and disengaging means has been completed the electric rotary device controlling means reduces a braking torque generated by the generator/motor by a set rate.

In this case, it is possible to reduce shock produced by torque fluctuations.

In another starting system of the invention, from the start of engaging of the engaging element by the engaging element engaging and disengaging means to the completion thereof the electric rotary device controlling means reduces the braking torque of the generator/motor.

In this case, it is possible to suppress the occurrence of inertia torque accompanying engagement of the engaging element and reduce engagement shock.

In another starting system of the invention there is provided a one-way clutch for transmitting a rotation of the generator/motor to the output shaft of the engine.

In this case, the generator motor can also be used as a starter motor, and when the engine is not running it is possible to start the engine by driving the generator/motor.

In another starting system of the invention the engaging element is a clutch of normally closed type and transmits a rotation of the generator/motor to the output shaft of the engine.

Therefore, the engaging element can be engaged and the generator/motor and the engine thereby connected even when the engine is not running and hydraulic pressure is not being produced in a hydraulic circuit. As a result, the generator/motor can also be used as a starter motor, and when the engine is not running it is possible to start the engine by driving the generator/motor.

When the engine is driven, a hydraulic pressure is produced in the hydraulic circuit and a hydraulic pressure is supplied to a hydraulic cylinder and the engaging element is released.

In another starting system of the invention, when the difference between a power obtained from regeneration by the generator/motor and a power consumed in driving the generator/motor is smaller than a set value and the speed of a gear element other than the first gear element obtained from the speed signal is larger than a set value for disengaging the engaging element engaging and disengaging means engages the engaging element.

In this case, because only the power obtained by regeneration with the generator/motor is consumed in driving the generator/motor, the capacity of the accumulator can be made small.

Another starting system of the invention comprises: a gearbox, having at least a first gear element connected to an output shaft of an engine, a second gear element connected to a driving wheel of a vehicle and a third gear element, for by applying a braking torque to the third gear element reducing the speed of a rotation inputted from the first gear element and outputting it to the second gear element; an engaging element connected to any of the gear elements for being selectively engaged and mechanically connecting the output shaft of the engine to the driving wheel; an electric rotary device connected to the third gear element; an accumulator; engine load detecting means for detecting an engine load; speed detecting means for detecting the speed of at least one of the gear elements of the gearbox and outputting a speed signal; and a control unit.

Also, the control unit comprises electric rotary device controlling means for setting a target speed of the first gear element based on the engine load and bringing the speed of the first gear element obtained from the speed signal to a target speed by driving the electric rotary device and causing the electric rotary device to generate a braking torque and engaging element engaging and disengaging means for comparing the speed of the first gear element when the engaging element has been engaged with a set value for disengaging and disengaging the engaging element based on the comparison results.

As a result, because it only has to put the engaging element into a semi-engaged state and perform feedback control of the engine speed, the output control unit can be simplified.

Fig. 1 is a function diagram of a starting system of a first preferred embodiment of the invention;

Fig. 2 is a schematic view of the starting system of the first preferred embodiment of the invention;

Fig. 3 is a schematic view of the starting system of the first preferred embodiment of the invention;

Fig. 4 is a speed line diagram of the first preferred embodiment of the invention;

Fig. 5 is a time chart of the starting system of the first preferred embodiment of the invention;

Fig. 6 is a first main flow chart of the operation of the starting system of the first preferred embodiment of the invention;

Fig. 7 is a second main flow chart of the operation of the starting system of the first preferred embodiment of the invention;

Fig. 8 is a map of target engine speeds in the first preferred embodiment of the invention;

Fig. 9 is a direct coupling clutch engagement and disengagement timing map of the first preferred embodiment of the invention;

Fig. 10 is a flow chart of a direct coupling clutch release control processing subroutine of the first preferred embodiment of the invention;

Fig. 11 is a time chart of the direct coupling clutch release control processing of the first preferred embodiment of the invention;

Fig. 12 is a flow chart of an N→D control processing subroutine of the first preferred embodiment of the invention;

Fig. 13 is a flow chart of a neutral control subroutine of the first preferred embodiment of the invention;

Fig. 14 is a time chart of setting up of a creep torque in the first preferred embodiment of the invention;

Fig. 15 is a time chart of setting up of a rapid starting torque in the first preferred embodiment of the invention;

Fig. 16 is a map of waiting time in the first preferred embodiment of the invention;

Fig. 17 is a flow chart of a direct coupling clutch engagement control processing subroutine of the first preferred embodiment of the invention;

Fig. 18 is a time chart of the direct coupling clutch engagement control processing subroutine of the first preferred embodiment of the invention;

Fig. 19 is a flow chart of a regeneration control processing subroutine in the first preferred embodiment of the invention;

Fig. 20 is a speed line diagram of when regeneration control is given priority in the first preferred embodiment of the invention;

Fig. 21 is a speed line diagram of when fuel cutoff is given priority in the first preferred embodiment of the invention;

Fig. 22 is an electricity generation efficiency map of a generator/motor in the first preferred embodiment of the invention;

Fig. 23 is a schematic view of a starting system of a second preferred embodiment of the invention;

Fig. 24 is a speed line diagram of the second preferred embodiment of the invention;

Fig. 25 is a schematic view of a starting system of a third preferred embodiment of the invention;

Fig. 26 is a speed line diagram of the third preferred embodiment of the invention;

Fig. 27 is a schematic view of a starting system of a fourth preferred embodiment of the invention;

Fig. 28 is a speed line diagram of the fourth preferred embodiment of the invention;

Fig. 29 is a schematic view of a starting system of a fifth preferred embodiment of the invention;

Fig. 30 is a speed line diagram of the fifth preferred embodiment of the invention;

Fig. 31 is a schematic view of a starting system of a sixth preferred embodiment of the invention;

Fig. 32 is a speed line diagram of the sixth preferred embodiment of the invention;

Fig. 33 is a time chart of a starting system of a seventh preferred embodiment of the invention;

Fig. 34 is a flow chart of a direct coupling clutch release control processing subroutine of the seventh preferred embodiment of the invention;

Fig. 35 is a time chart of the direct coupling clutch release control processing of the seventh preferred embodiment of the invention;

Fig. 36 is a deviation constant map of the seventh preferred embodiment of the invention;

Fig. 37 is a flow chart of a direct coupling clutch engagement control processing subroutine of the seventh preferred embodiment of the invention;

Fig. 38 is a time chart of a starting system of an eighth preferred embodiment of the invention;

Fig. 39 is a flow chart of a direct coupling clutch engagement control processing subroutine of the eighth preferred embodiment of the invention;

Fig. 40 is a schematic view of a starting system of a ninth preferred embodiment of the invention;

Fig. 41 is a time chart of the starting system of the ninth preferred embodiment of the invention;

Fig. 42 is a flow chart of a direct coupling clutch engagement control processing subroutine of the ninth preferred embodiment of the invention;

Fig. 43 is a time chart of a starting system of a tenth preferred embodiment of the invention;

Fig. 44 is a flow chart of a direct coupling clutch engagement control processing subroutine of the tenth preferred embodiment of the invention; and

Fig. 45 is a time chart of starting system of an eleventh preferred embodiment of the invention.

Preferred embodiments of the invention will now be described in detail with reference to the accompanying drawings.

Fig. 1 is a function diagram of a starting system of a first preferred embodiment of the invention.

As shown in Fig. 1, a starting system of the invention comprises: a gearbox 16 which has at least a first gear element 81 connected to an output shaft of an engine 11, a second gear element 82 connected to vehicle driving wheels 25 and a third gear element 83, and by applying a braking torque to the third gear element 83 reduces the speed of a rotation inputted from the first gear element 81 and outputs it to the second gear element 82; an engaging element 87 connected to either the first gear element 81, the second gear element 82 or the third gear element 83 and selectively engaged and thereby mechanically connected to the output shaft of the engine 11 and the vehicle driving wheels 25; an electric rotary device M connected to the third gear element 83; a main battery 47 serving as an accumulator; a throttle sensor 29 serving as engine load detecting means for detecting the throttle opening of the engine as an engine load; speed detecting means 86 for detecting the speed of at least one of the gear elements of the gearbox 16 and outputting a speed signal; and a control unit 90.

In this case, the speed detecting means 86 may alternatively directly detect the speed of all the gear elements or calculate a speed based on the speeds of two of the gear elements.

The control unit 90 comprises electric rotary device controlling means 93 for bringing the speed of the first gear element 81 obtained from the speed signal to a target speed by driving the electric rotary device M and generating a braking torque and engaging element engaging and disengaging means 95 for comparing the speeds of the other gear elements obtained from the speed signal to set values for engaging and disengaging and engaging and disengaging the engaging element 87 based on the comparison results.

Fig. 2 is a schematic view of the starting system of the first preferred embodiment of the invention.

In Fig. 2, 11 is the engine (E/G), 12 is an engine output shaft by which rotation generated by the engine 11 is transmitted and M1 is a generator/motor serving as an electric rotary device. The generator/motor M1 acts as a generator

and as a motor; when acting as a generator, it generates a regeneration current and applies a braking torque to the engine output shaft 12 as a reaction, and when acting as a motor it generates a torque and outputs it to an output shaft 19.

A resolver 15 detects magnetic pole positions of the generator/motor M1; the gearbox 16 is connected to the engine output shaft 12; 18 is a starting mechanism made up of the resolver 15, the generator/motor M1 and the gearbox 16; and 19 is an output shaft for transmitting rotation generated by the starting mechanism 18 to a transmission 21. In this preferred embodiment the transmission 21 is an automatic transmission (A/T), but it may alternatively be a manual transmission.

The gearbox 16 has a speed-reducing gear mechanism not shown in the drawings, for example a planetary gear unit, and has a clutch not shown in the drawings which can selectively engage and disengage the elements of the planetary gear unit. This clutch is engaged and disengaged by a hydraulic servo, not shown in the drawings, of a hydraulic circuit 23. The hydraulic circuit 23 has a solenoid valve SC for selectively supplying oil to the hydraulic servo.

In this preferred embodiment, because the transmission 21 is an automatic transmission, the hydraulic circuit 23 has solenoid valves S1, S2 for selecting the gears of the transmission 21.

When a gear is selected by the hydraulic circuit 23, a rotation corresponding to that gear is transmitted via a drive shaft 24 to the vehicle driving wheels 25.

By depressing an accelerator pedal 28 it is possible to change the throttle opening as an engine load. The throttle opening is detected by a throttle sensor 29 serving as engine load detecting means linked to the accelerator pedal 28. An engine speed sensor 30 is disposed facing the engine output shaft 12 and detects the engine speed, an output speed sensor 31 is disposed facing the output shaft 19 and detects the output speed of the starting mechanism 18, a shift position switch (N.S.S/W) 33 is linked to a shift lever not shown in the drawings serving as operating means and detects a range and gear selected by said shift lever, and a vehicle speed sensor 34 serving as vehicle speed detecting means is disposed facing the drive shaft 24 and detects a value corresponding to the vehicle speed (hereinafter referred to as 'the vehicle speed correspondent value'). In practice, the speed of the drive shaft 24 is detected by the vehicle speed sensor 34 and converted into the vehicle speed correspondent value by calculation.

In this preferred embodiment, the engine speed sensor 30 is disposed facing the engine output shaft 12 and detects the speed of the engine output shaft 12; however, alternatively it is possible to use a signal from an ignition system instead of the speed of the engine output shaft 12. Also, although in this preferred embodiment the output speed sensor 31 is disposed facing the output shaft 19 and detects the speed of the output shaft 19, the speed of the input shaft of the transmission 21 can alternatively be detected instead of the speed of the output shaft 19.

In an automatic transmission control unit 36, a starting output and a gear-change output are generated based on the throttle opening detected by the throttle sensor 29, the vehicle speed detected by the vehicle speed sensor 34 and the range and gear detected by the shift position switch 33, a clutch signal corresponding to the starting output is outputted to the solenoid of the solenoid valve SC and solenoid signals corresponding to the gear-change output are outputted to the solenoids of the solenoid valves S1, S2.

The hydraulic circuit 23 supplies hydraulic pressure to the above-mentioned hydraulic servo based on the clutch signal and the solenoid signals received by the solenoids, selects gears and directly couples the starting mechanism 18.

An ignition switch 39 produces a start signal when a driver turns an ignition key, a brake sensor 41 serving as Drake detecting means detects a brake stroke or a brake fluid pressure when the driver depresses a brake pedal 42 and thereby detects a braking force called for by the driver, and a fuel injection control unit 44 (EFIECU) receives a neutral signal generated by the automatic transmission control unit 36 and reduces a fuel injection quantity in the engine 11.

An output control unit 46 drives the generator/motor M1 and thereby produces a torque required to start the vehicle moving; the main battery 47 serves as an electricity storing device for supplying current for driving the generator/motor M1 and receiving and storing electrical energy obtained by regeneration, and a remaining charge detecting device 48 detects remaining charge of the main battery 47 and monitors the charge state thereof based on voltage and current integrated values or the like.

An operation signal SG1 is outputted from the automatic transmission control unit 36 to the output control unit 46, and this operation signal SG1 is made up of an ON/OFF signal of a switching device for controlling the current supplied to the generator/motor M1 and a chopper duty signal and the like. An operation signal SG2 is outputted from the output control unit 46 to the automatic transmission control unit 36, and this operation signal SG2 is used as a current monitor signal for conducting feedback control in the automatic transmission control unit 36.

The operation of the starting system thus constructed will be now described.

Fig. 3 is a schematic view of the starting system of this first preferred embodiment of the invention, Fig. 4 is a speed line diagram of the first preferred embodiment of the invention and Fig. 5 is a time chart of the starting system of the first preferred embodiment of the invention.

In the figures, 11 is the engine, 12 is the engine output shaft, M1 is the generator/motor, 16 is the gearbox, 18 is the starting mechanism, 19 is the output shaft of the starting mechanism 18, 21 is the transmission and 50 is a starting mechanism case.

The gearbox 16 consists of a planetary gear unit, and this planetary gear unit is made up of a sun gear S, a pinion P, a ring gear R and a carrier C rotatably supporting the pinion P, the sun gear S is fixed to the engine output shaft 12

and the carrier C is fixed to the output shaft 19. The generator/motor M1 is made up of a rotor 51 and a stator 52, the rotor 51 is fixed to the ring gear R and the stator 52 is fixed to the starting mechanism case 50. The sun gear S, the carrier C and the ring gear R constitute the gear elements of the planetary gear unit.

A direct coupling clutch CL serving as an engaging element is disposed between the ring gear R and the engine output shaft 12, and by engaging this direct coupling clutch CL the ring gear R and the sun gear S can be locked together and the gearbox 16 thereby directly coupled. In this preferred embodiment the ring gear R and the sun gear S are locked together, but it is also possible to lock together the ring gear R and the carrier C or the carrier C and the sun gear S.

In the starting system thus constructed, when the vehicle is stationary, normally the neutral range is selected, the throttle opening θ is set to an idling throttle opening θ_{idl} and the engine is run at an idling speed N_{idl}. At this time, the rotation of the engine 11 is transmitted to the starting mechanism 18 via the engine output shaft 12 and sun gear S is rotated at the idling speed N_{idl}.

Next, when to start the vehicle moving a shift lever not shown in the drawings is operated and a D range is selected and a clutch for forward movement (hereinafter referred to as 'the forward clutch'), not shown in the drawings, of the transmission 21 is engaged.

At this time the rotation at the idling speed N_{idl} is transmitted to the sun gear S, but the forward clutch being engaged causes the inertia of the vehicle to be transmitted to the output shaft 19, and the speed of the carrier C and the output shaft 19, that is, the output speed N_o, becomes 0. As a result, the speed line of the system becomes the speed line L1 in the speed line diagram of Fig. 4 and the generator/motor M1 is rotated as a load and enters a regenerating state while exerting a braking torque T_{m1}.

When the driver then depresses the accelerator pedal 28 (Fig. 2) and increases the throttle opening θ from the idling throttle opening θ_{idl} to a throttle opening θ_m, a target engine speed N_e^* corresponding to the throttle opening θ_m is set and in the automatic transmission control unit 36 feedback control is performed so that the braking torque T_{m1} generated by the generator/motor M1 is produced and the target engine speed N_e^* is maintained. At this time, along with the feedback control, because a torque is transmitted to the output shaft 19, the output speed N_o also gradually increases.

When at a time t1 the generator/motor speed N_{m1} becomes 0, the generator/motor M1 shifts from the regenerating state into a driving state. At this time, the speed line becomes the line L2.

Thereafter, as acceleration is continued, the generator/motor speed N_{m1} continues to rise while the target engine speed N_e^* is maintained unchanged. When at a time t2 the output speed N_o becomes greater than a set value for engaging N_{el} among the above-mentioned set values for engaging and disengaging, the clutch signal outputted from the automatic transmission control unit 36 to the solenoid of the solenoid valve SC becomes ON and the direct coupling clutch CL is engaged. The output speed N_o in this case can be calculated from the following equation, wherein i is a gear ratio:

$$N_o = (N_e - N_{m1})/i + N_{m1} \ (N_{m1} < 0)$$

The set value for engaging N_{el} is set higher by a predetermined value than a minimum speed N_{emin} at which engine stalling does not occur when as a result of the direct coupling clutch CL being engaged the rotation at the target engine speed N_e^* is transmitted to the ring gear R rotating at the generator/motor speed N_{m1}.

In this way, when the gearbox 16 becomes directly coupled, the rotation of the engine output shaft 12 is transmitted unchanged to the output shaft 19. As a result, the engine speed N_e, the output speed N_o and the generator/motor speed N_{m1} become equal and the speed line becomes the line L3. The generator/motor M1 shifts into a non-driving state. In this case, the braking torque T_{m1} is reduced gradually in order to reduce shock caused by torque fluctuation.

As a result, whenever the vehicle is started moving, of the kinetic energy produced by the engine 11, excess kinetic energy is used to rotate as a load the generator/motor M1 braked by the braking torque and is converted by the generator/motor M1 into electrical energy. Current generated by the generator/motor M1 in the regenerating state can be stored in the main battery 47. This stored electrical energy can be used to run electrical equipment of the vehicle or auxiliary equipment of the engine or to drive the generator/motor M1. As a result, it is possible to improve the fuel consumption of the vehicle.

Because the direct coupling clutch CL is engaged when the output speed N_o becomes greater than the set value for engaging N_{el}, not only can engine stalling be prevented from occurring but also it is possible to directly transmit kinetic energy produced by the engine 11 to the driving wheels 25 without it being converted into electrical energy, and therefore fuel consumption can be improved in this way also.

During gear-changing of the transmission 21, a gear-change shock occurs due to inertia torque; however, by temporarily putting the starting system into the regenerating state when the transmission 21 is in a gear-changing transient state, the torque inputted into the transmission 21 can be reduced and the occurrence of gear-change shock can be prevented.

Also, it is possible to make the starting mechanism 18 have the function of an auxiliary transmission. That is, if an open ratio transmission 21 is used as a main transmission and a starting mechanism 18 with relatively small gear ratios is used as an auxiliary transmission, a cross-ratio multistage automatic transmission is obtained.

In this case, the direct coupling clutch CL can be changed over between the engaged state and the disengaged state in each gear of the main transmission.

Next, the operation of the starting system constructed as described above will be described based on flow charts.

Fig. 6 is a main flow chart of the operation of the starting system of the first preferred embodiment of the invention, Fig. 7 is a second main flow chart of the operation of the starting system of the first preferred embodiment of the invention and Fig. 8 is a map of target engine speeds in the first preferred embodiment of the invention.

Step S1: All settings are reset at the start of control.

Step S2: The speed detecting means 86 (Fig. 1) calculates the engine speed N_e (Fig. 5), the output speed N_o, the generator/motor speed N_{m1} and the vehicle speed correspondent value V based on signals sent from sensors such as the engine speed sensor 30 (Fig. 2), the output speed sensor 31 and the vehicle speed sensor 34. In this case, the engine speed N_e, the output speed N_o and the generator/motor speed N_{m1} not only can be obtained directly based on the signals from the respective sensors but also can be calculated based on two other speeds.

Step S3: Shift position switch processing is carried out. That is, a range and gear are detected by the shift position switch 33 and fail determination of the shift position switch 33 itself is carried out.

Step S4: The throttle opening θ is calculated based on a signal sent from the throttle sensor 29.

Step S5: Based on a brake signal sent from the brake sensor 41, a brake stroke or a brake fluid pressure is detected and a braking force being called for by the driver is calculated.

Step S6: The present state of the generator/motor M1 is determined from its voltage, speed and direction of rotation.

Step S7: The charge state, i.e. the remaining charge, of the main battery 47 is detected.

Step S8: It is determined whether or not the range detected in Step S3 is the P range or the N range.

Step S9: The direct coupling clutch CL (Fig. 3) is released and the braking torque T_{m1} of the generator/motor M1 is made 0.

Step S10: It is determined whether the clutch signal for engaging and disengaging the direct coupling clutch CL is ON or whether or not a flag LFSC which will be further discussed later is A. When the clutch signal is ON or the flag LFSC is A processing proceeds to Step S11, and when the clutch signal is not ON or the flag LFSC is not A processing proceeds to Step S12.

Step S11: The engaging element engaging and disengaging means 95 executes direct coupling clutch release control processing.

Step S12: It is determined whether or not N→D control processing has just been executed (or is being executed). When it has just been executed (or is being executed) processing proceeds to Step S13, and when not processing proceeds to Step S14.

Step S13: N→D control processing is executed.

Step S14: It is determined whether or not the throttle opening θ has been set to the idling throttle opening θ_{idl}. When it has been set to the idling throttle opening θ_{idl}, processing proceeds to Step S15, and when it has not been set to the idling throttle opening θ_{idl} processing proceeds to Step S17.

Step S15: Neutral control processing is executed.

Step S16: The target engine speed N_e^* is reset and feedback control is discontinued.

Step S17: Because the accelerator pedal 28 (Fig. 2) is being depressed, the target engine speed N_e^* corresponding to the throttle opening θ is read from the target engine speed map of Fig. 8 and is set. The target engine speed N_e^* is made larger the larger the throttle opening θ becomes, and when the throttle opening θ becomes greater than a predetermined value the target engine speed N_e^* is made constant. In this way it is possible to obtain a characteristic approximating to the stall speed of a torque convertor.

Step S18: The engaging element engaging and disengaging means 95 executes direct coupling clutch engagement control processing.

Step S19: When the throttle opening θ has been set to the idling throttle opening θ_{idl}, regeneration control processing is executed and the target engine speed N_e^* is reset.

Step S20: Motor control output is carried out. That is, while monitoring the operation signal SG2 the electric rotary device controlling means 93 performs feedback control of the braking torque T_{m1} (or the generator/motor speed N_{m1}) and outputs control command values as the operation signal SG1 to an invertor of the output control unit 46 so that the previously set target engine speed N_e^* is maintained.

Step S21: The clutch signal is outputted to the solenoid of the solenoid valve SC.

Next, the direct coupling clutch release control processing subroutine of Step S11 in Fig. 6 will be described.

Fig. 9 is a direct coupling clutch engagement and disengagement timing map of the first preferred embodiment of the invention, Fig. 10 is a flow chart of the direct coupling clutch release control processing subroutine of the first preferred embodiment of the invention and Fig. 11 is a time chart of the direct coupling clutch release control processing of the first preferred embodiment of the invention.

Step S11-1: It is determined whether or not a flag LFSC indicating the engaged/disengaged state of the direct coupling clutch CL is 0. When it is 0 processing proceeds to Step S11-2 and when it is not 0 processing proceeds to

Step S11-8. When the direct coupling clutch CL is not in an engaging transient state the flag LFSC becomes 0 and when the direct coupling clutch CL is in a releasing transient state the flag LFSC becomes A.

Step S11-2: Based on the battery remaining charge determination of Step S7, determination of whether priority is to be given to fuel cutoff or whether priority is to be given to regeneration control is carried out.

Step S11-3: Based on the result of the determination of whether priority is to be given to fuel cutoff or whether priority is to be given to regeneration control, a set value for release N_{el}' among the above-mentioned set values for engaging and disengaging of the direct coupling clutch CL is read from the direct coupling clutch engagement and disengagement timing map of Fig. 9 and is set. A first set value for release N_{el}' is used when priority is to be given to regeneration control and a second set value for release N_{el}' is used when priority is to be given to fuel cutoff, and the first set value for release N_{el}' is set lower than the second set value for release N_{el}'. In Fig. 11, the clutch signal is made ON and OFF based on the second set value for release N_{el}'.

As shown in Fig. 9, when at times such as when the acceleration demand is high the throttle opening θ becomes large the set value for release N_{el}' and the set value for engaging N_{el} are made high. As a result, the direct coupling clutch CL can be released quickly and engaged slowly.

Step S11-4: It is determined whether or not the output speed N_o is smaller than the set value for release N_{el}'. When the output speed N_o is smaller than the set value for release N_{el}' processing proceeds to Step S11-5 and when the output speed N_o is greater than the set value for release N_{el}' processing returns.

Step S11-5: The clutch signal is made OFF.

Step S11-6: Because when the clutch signal is made OFF the direct coupling clutch CL is not immediately released, the flag LFSC is set to A and the releasing transient state is monitored.

Step S11-7: To make the shift from the engine speed N_e to the target engine speed N_e^* smooth, the initial torque T_{mi} of the generator/motor M1 (Fig. 2) is set. The set value for release N_{el}' when priority is to be given to regeneration control is obtained by setting the throttle opening θ to the idling throttle opening θ_{idl}.

Step S11-8: It is determined whether or not the flag LFSC is A. When it is A processing proceeds to Step S11-9 and when it is not A processing returns.

Step S11-9: It is determined whether or not the absolute value of the difference between the engine speed N_e and the output speed N_o is larger than a set value K_3. When the absolute value of the difference between the engine speed N_e and the output speed N_o is larger than the set value K_3 processing proceeds to Step S11-10, and when the absolute value of the difference between the engine speed N_e and the output speed N_o is smaller than the set value K_3 processing returns.

Step S11-10: It is determined whether or not the direct coupling clutch CL has actually been released, and the flag LFSC is set to 0.

Step S11-11: Because the releasing transient state of the direct coupling clutch CL has ended, the initial torque T_{mi} of the generator/motor M1 is reset. As a result, the braking torque T_{m1} is determined by the feedback control for maintaining the target engine speed N_e^*.

Next, the N→D control processing subroutine of Fig. 7 will be described.

Fig. 12 is a flow chart of the N→D control processing subroutine of the first preferred embodiment of the invention, Fig. 13 is a flow chart of the neutral control subroutine of the first preferred embodiment of the invention, Fig. 14 is a time chart of the setting up of a creep torque in the first preferred embodiment of the invention, Fig. 15 is a time chart of the setting up of a rapid starting torque in the first preferred embodiment of the invention and Fig. 16 is a map of waiting time in the first preferred embodiment of the invention.

Step S13-1: Immediately after N→D control processing is executed, or during N→D control processing execution, a flag LFND is set to 1. This flag LFND is 1 when indicating that N→D control processing has just been executed or is being executed and otherwise is 0.

Step S13-2: When an N→D output is outputted at a time t3, based on the throttle opening θ a waiting time td until the forward clutch engages is read from the waiting time map (Fig. 16) and is set. The waiting time td is the time from when the N→D output is outputted to when the forward clutch is engaged, and the waiting time td becomes shorter as the throttle opening θ becomes larger.

Step S13-3: It is determined whether or not the elapsed time t from the time t3 is greater than the waiting time td. When the elapsed time t is greater than the waiting time td processing proceeds to Step S13-4 and when the elapsed time t is shorter than the waiting time td processing proceeds to Step S13-8.

Step S13-4: To determine the starting state of the vehicle, it is determined whether or not the throttle opening θ has been set to the idling throttle opening θ_{idl}. When it has been set to the idling throttle opening θ_{idl} processing proceeds to Step S13-5, and when it has not been set to the idling throttle opening θ_{idl} processing proceeds to Step S13-9.

Step S13-5: When the throttle opening θ is the idling throttle opening θ_{idl} the system is determined to be in a normal starting state and torque setting up means not shown in the drawings sets up a creep torque T_c during a transition time ts. That is, by gradually increasing the braking torque T_{m1} of the generator/motor M1 (Fig. 2), the torque T outputted from the starting mechanism 18 is swept up to a creep torque T_c. In this way, after an N→D output is outputted, because current flows through the generator/motor M1, it is possible to prevent an engagement shock accompanying the N→D

changeover. Also, because current flows through the generator/motor M1, it is possible to generate a creep force similar to that of a conventional torque convertor.

Step S13-6: It is determined whether or not the setting up of the creep torque T_c has been completed. When the setting up of the creep torque T_c has been completed processing proceeds to Step S13-7, and when it has not been completed processing proceeds to Step S13-8.

Step S13-7: The flag LFND is set to 0.

Step S13-8: Because the throttle opening θ is the idling throttle opening θ_{idl}, the target engine speed N_e^* is reset.

Step S13-9: Because the throttle opening θ is not the idling throttle opening θ_{idl}, the target engine speed N_e^* corresponding to the throttle opening θ is set.

Step S13-10: When in the D range the throttle opening θ has been suddenly increased, the system is determined to be in a rapid starting state and a rapid starting torque T* is set up. In this case, because the throttle opening θ is large the waiting time td is made small and the torque T is swept up to a rapid starting torque T* higher than the creep torque T_c during the transition time ts. The rapid starting torque T* is a potential torque T corresponding to the target engine speed N_e^*, and in practice the engine speed N_e is brought to the target engine speed N_e^*.

Step S13-11: It is determined whether or not the setting up of the rapid starting torque T* has been completed and the engine speed N_e has become the target engine speed N_e^*. When the engine speed N_e has become the target engine speed N_e^* processing proceeds to Step S13-12 and when the engine speed N_e has not reached the target engine speed N_e^* processing returns.

Step S13-12: The flag LFND is set to 0.

Next, the neutral control processing will be described.

Step S15-1: The output speed N_o is divided by the gear ratio i of the transmission 21 (Fig. 2) and the vehicle speed correspondent value V is calculated, and it is determined whether or not the vehicle speed correspondent value V is less than a set value V_x. When there is no transmission 21 on the output side of the gearbox 16, the gear ratio i is made 1. It is also possible to use a vehicle speed correspondent value V already calculated based on a speed detected by the vehicle speed sensor 34.

When the vehicle speed correspondent value V is less than the set value V_x processing proceeds to Step S15-2, and when the vehicle speed correspondent value V is greater than the set value V_x processing returns.

Step S15-2: It is determined whether or not the brake pedal 42 has been depressed and a brake signal sent from the brake sensor 41 is ON. When the brake signal is ON processing proceeds to Step S15-3 and when the brake signal is OFF processing proceeds to Step S15-6. In this case, the throttle opening θ is the idling throttle opening θ_{idl}, and when the brake signal is ON a neutral control state is established.

Step S15-3: With the time at which the brake pedal 42 was depressed and the brake signal became ON as a starting point, timing by a timer not shown in the drawings for preventing busy shift is commenced and it is determined whether or not the elapsed time t is greater than a set time tb. When the elapsed time t is greater than the set time tb processing proceeds to Step S15-4 and when the elapsed time t is shorter than the set time tb processing returns.

Step S15-4: A flag LFNC indicating that neutral control processing is being executed is set to 1.

Step S15-5: While neutral control processing is being executed the braking torque T_{m1} is made 0.

Step S15-6: It is determined whether or not the flag LFNC is 1. When the flag LFNC is 1 processing proceeds to Step S15-7 and when the flag LFNC is not 1 processing returns.

Step S15-7: The normal starting state creep torque T_c is set up.

Step S15-8: It is determined whether or not the transition time ts has elapsed and the setting up of the creep torque T_c has been completed. When the setting up of the creep torque T_c has been completed processing proceeds to Step S15-9, and when setting up of the creep torque T_c has not been completed processing returns.

Step S15-9: The flag LFNC is set to 0.

Next, the direct coupling clutch engagement control processing subroutine of Fig. 7 will be described.

Fig. 17 is a flow chart of the direct coupling clutch engagement control processing subroutine of the first preferred embodiment of the invention and Fig. 18 is a time chart of the direct coupling clutch engagement control processing subroutine of the first preferred embodiment of the invention.

Step S18-1: It is determined whether or not the flag LFSC is 0. When the flag LFSC is 0 processing proceeds to Step S18-2, and when the flag LFSC is not 0 processing proceeds to Step S18-6.

Step S18-2: The set value for engaging N_{el} of the direct coupling clutch CL (Fig. 3) is read from the direct coupling clutch engagement and disengagement timing map of Fig. 9 and is set.

Step S18-3: The output speed N_o and the set value for engaging N_{el} are compared and it is determined whether or not the output speed N_o is greater than the set value for engaging N_{el}. When the output speed N_o is greater than the set value for engaging N_{el} processing proceeds to Step S18-4, and when the output speed N_o is below the set value for engaging N_{el} processing returns.

Step S18-4: At a time t5 the clutch signal is made ON.

Step S18-5: The flag LFSC is set to 1.

Step S18-6: It is determined whether or not the flag LFSC is 1. When the flag LFSC is 1 processing proceeds to Step S18-7 and when the flag LFSC is not 1 processing proceeds to Step S18-10.

Step S18-7: It is determined whether or not the difference between the target engine speed N_e* and the engine speed N_e is larger than a set value K_1. When the difference is larger than the set value K_1 processing proceeds to Step S18-8 and when the difference is smaller than the set value K_1 processing returns.

Step S18-8: At a time t6 the flag LFSC is set to 2.

Step S18-9: The engine speed N_e is reset and feedback control is discontinued.

Step S18-10: It is determined whether or not the flag LFSC is 2. When the flag LFSC is 2 processing proceeds to Step S18-11, and when the flag LFSC is not 2 processing proceeds to Step S18-14.

Step S18-11: It is determined whether or not the difference between the engine speed N_e and the output speed N_o is smaller than a set value K_2. When the difference is smaller than the set value K_2 processing proceeds to Step S18-13, and when the difference is larger than the set value K_2 processing proceeds to Step S18-12.

Step S18-12: At the time t6 torque reduction control is commenced in correspondence with the throttle opening θ and the braking torque T_{m1} is reduced by a predetermined amount. In this way, the occurrence of inertia torque accompanying the engagement of the direct coupling clutch CL is suppressed and engagement shock is reduced. When at a time t7 the difference between the engine speed N_e and the output speed N_o becomes smaller than a set value G_1, torque reduction control is ended. In this case, the braking torque T_{m1} is swept up to its original value within a set time.

Step S18-13: At a time t8 the flag LFSC is set to 3.

Step S18-14: It is determined whether or not the flag LFSC is 3. When the flag LFSC is 3 processing proceeds to Step S18-15, and when the flag LFSC is not 3 processing proceeds to Step S18-17.

Step S18-15: Ending control processing is executed and the braking torque T_{m1} is swept down to 0 within a set time.

Step S18-16: It is determined whether or not ending control processing is being executed. When ending control processing is being executed and the braking torque T_{m1} has not become 0 processing returns, and when ending control is not being executed and the braking torque T_{m1} has become 0 processing proceeds to Step S18-17.

Step S18-17: When the entire ending control process has been completed the flag LFSC is reset to 0.

Next, the regeneration control processing subroutine of Step S19 of Fig. 7 will be described.

Fig. 19 is a flow chart of the regeneration control processing subroutine in the first preferred embodiment of the invention, Fig. 20 is a speed line diagram of when regeneration control is given priority in the first preferred embodiment of the invention, Fig. 21 is a speed line diagram of when fuel cutoff is given priority in the first preferred embodiment of the invention and Fig. 22 is an electricity generation efficiency map of the generator/motor in the first preferred embodiment of the invention.

Step S19-1: It is determined whether or not the throttle opening θ has been set to the idling throttle opening θ_{idl}. When it has been set to the idling throttle opening θ_{idl} processing proceeds to Step S19-2, and when it has not been set to the idling throttle opening θ_{idl} processing returns.

Step S19-2: The output speed N_o is divided by the gear ratio i of the transmission 21 (Fig. 2) and the vehicle speed correspondent value V is calculated, and it is determined whether or not the vehicle speed correspondent value V is less than a set value V_x. When there is no transmission 21 on the output side of the gearbox 16, the gear ratio is made 1. It is also possible to use a vehicle speed correspondent value V already calculated based on a speed detected by the vehicle speed sensor 34.

When the vehicle speed correspondent value V is below the set value V_x processing returns, and when the vehicle speed correspondent value V is larger than the set value V_x processing proceeds to Step S19-3.

Step S19-3: Because the vehicle is known to be coasting down it is determined whether or not the clutch signal is ON. When the clutch signal is ON processing proceeds to Step S19-4, and when it is not ON processing proceeds to Step S19-5.

Step S19-4: Regeneration control is carried out and the braking torque T_{m1} is determined according to the brake braking force.

Steps S19-5, S19-6: When the vehicle is coasting down and the direct coupling clutch CL has been released, the generator/motor M1 can be independently controlled and in this state it is determined whether or not priority is to be given to fuel cutoff. In this case, whether or not priority is to be given to fuel cutoff is determined according to the battery remaining charge determination of Step S7. When there is a lot of remaining charge, because there is no need to regenerate, fuel cutoff is given priority and processing proceeds to Step S19-7; when there is little remaining charge, because regeneration is necessary, processing proceeds to Step S19-8.

Step S19-7: A preset target engine speed N_e* (FC) for fuel cutoff is set so that the engine speed N_e becomes higher than a fuel cutoff return point (1400rpm). As shown in the speed line diagram of Fig. 21, the generator/motor speed N_{m1} can be reduced and the engine speed N_e increased.

For example, when during coasting down the engine speed N_e nears 1400 (rpm) (point A' in Fig. 22), the direct coupling clutch CL is released, the generator/motor speed N_{m1} is reduced (point B in Fig. 22) and the engine speed N_e is increased. Because the engine speed N_e increases it is possible to continue the fuel cutoff and improve fuel consumption.

Step S19-8: When priority is not given to fuel cutoff and is given to regeneration control, a generation torque T_{m1g} of the generator/motor M1 is determined according to the brake braking force.

Here, in Fig. 20, it is supposed that the motor generation efficiency is high when the generator/motor speed N_{m1} is kept in the high generation efficiency region between a minimum value N_{m1a} and a maximum value N_{m1b}. Accordingly, when the clutch signal is made ON and regeneration is being carried out with the direct coupling clutch CL engaged, as shown by the speed line L4, when the generator/motor speed N_{m1} falls and becomes the minimum value N_{m1a} the clutch signal is made OFF and the direct coupling clutch CL is released. As a result, it is possible to increase the generator/motor speed N_{m1} and keep it in the high generation efficiency region between the minimum value N_{m1a} and the maximum value N_{m1b} and the amount of electrical power regenerated can thereby be increased.

Step S19-9: Based on the generation torque T_{m1g}, engine torque data is read out and a target engine speed N_e* (RG) for regeneration is calculated. At the point A of the generation efficiency map of Fig. 22, the generation efficiency can be made high.

Step S19-10: The calculated target engine speed N_e* (RG) for regeneration is set.

A second preferred embodiment of the invention will now be described.

Fig. 23 is a schematic view of a starting system of a second preferred embodiment of the invention, and Fig. 24 is a speed line diagram of the second preferred embodiment of the invention.

In Fig. 23, 11 is an engine, 12 is an engine output shaft, M1 is a generator/motor, 16 is a gearbox, 18 is a starting mechanism, 19 is an output shaft of the starting mechanism 18, 21 is a transmission and 50 is a starting mechanism case.

The gearbox 16 comprises a double planetary gear unit, and this double planetary gear unit is made up of a sun gear S, pinions P_1 and P_2, a ring gear R and a carrier C rotatably supporting the pinions P_1 and P_2; the sun gear S is fixed to the engine output shaft 12 and the carrier C is fixed to a generator/motor rotary shaft 55. The generator/motor M1 is made up of a rotor 51 and a stator 52, the rotor 51 is fixed to the generator/motor rotary shaft 55 and the stator 52 is fixed to the starting mechanism case 50. The ring gear R is fixed to the output shaft 19.

A direct coupling clutch CL is disposed between the generator/motor rotary shaft 55 and the engine output shaft 12, and by this direct coupling clutch CL being engaged the carrier C and the sun gear S can be locked together and the gearbox 16 thereby directly coupled. In this preferred embodiment the carrier C and the sun gear S are locked together, but alternatively the ring gear R and the carrier C or the ring gear R and the sun gear S may be locked. In this case, because a double planetary gear unit is used, the reduction ratio of the gearbox 16 can easily be set to a value in the vicinity of 2.

In the starting system thus constructed, when to start the vehicle moving a shift lever not shown in the drawings is operated and a D range is selected, rotation at an idling speed N_{idl} (Fig. 5) is transmitted to the sun gear S, but as a result of the forward clutch being engaged the inertia of the vehicle is transmitted to the output shaft 19 and the output speed N_o is 0. As a result, the speed line is the line L6 in the speed line diagram of Fig. 24 and the generator/motor M1 is rotated as a load and enters a regenerating state.

When the driver then depresses the accelerator pedal 28 (Fig. 2) and increases the throttle opening θ from the idling throttle opening θ_{idl} to a throttle opening θ_m, a target engine speed N_e* corresponding to the throttle opening θ_m is set, when the driver depresses the accelerator pedal 28 further and increases the throttle opening θ a target engine speed N_e* corresponding to the throttle opening θ_m is set, and in the automatic transmission control unit 36 feedback control is carried out so that a braking torque T_{m1} produced by the generator/motor M1 is produced and the target engine speed N_e* is maintained. At this time, along with the feedback control, because a torque is transmitted to the output shaft 19, the output shaft speed N_o also gradually increases. When the generator/motor speed N_{m1} becomes 0, the generator/motor M1 shifts from the regenerating state to a driving state. At this time the speed line becomes the line L7.

Thereafter, as acceleration is continued, the generator/motor speed N_{m1} continues to rise while the target engine speed N_e* is maintained unchanged. When the direct coupling clutch CL is engaged and the gearbox 16 becomes directly coupled, the rotation of the engine output shaft 12 is transmitted unchanged to the output shaft 19. As a result, the engine speed N_e, the output speed N_o and the generator/motor speed N_{m1} become equal and the speed line becomes the line L8.

A third preferred embodiment of the invention will now be described.

Fig. 25 is a schematic view of a starting system of a third preferred embodiment of the invention, and Fig. 26 is a speed line diagram of the third preferred embodiment of the invention.

In Fig. 25, 11 is an engine, 12 is an engine output shaft, M1 is a generator/motor, 16 is a gearbox, 18 is a starting mechanism, 19 is an output shaft of the starting mechanism 18, 21 is a transmission and 50 is a starting mechanism case.

The gearbox 16 comprises a planetary gear unit, and this planetary gear unit is made up of a sun gear S, a pinion P, a ring gear R and a carrier C rotatably supporting the pinion P; the sun gear S is fixed to the generator/motor rotary shaft 55, the carrier C is fixed to the output shaft 19 and the ring gear R is fixed to the engine output shaft 12. The generator/motor M1 is made up of a rotor 51 and a stator 52, the rotor 51 is fixed to the generator/motor rotary shaft 55 and the stator 52 is fixed to the starting mechanism case 50.

A direct coupling clutch CL is disposed between the generator/motor rotary shaft 55 and the engine output shaft 12, and by this direct coupling clutch CL being engaged the ring gear R and the sun gear S can be locked together and

the gearbox 16 thereby directly coupled. In this preferred embodiment the ring gear R and the sun gear S are locked together, but alternatively the ring gear R and the carrier C or the carrier C and the sun gear S may be locked.

In the starting system thus constructed, when to start the vehicle moving a shift lever not shown in the drawings is operated and a D range is selected, rotation at an idling speed N_{idl} (Fig. 5) is transmitted to the sun gear S, but as a result of the forward clutch being engaged the inertia of the vehicle is transmitted to the output shaft 19 and the output speed N_o is 0. As a result, the speed line becomes the line L9 in the speed line diagram of Fig. 26 and the generator/motor M1 is rotated as a load and is in a regenerating state.

When the driver then depresses the accelerator pedal 28 (Fig. 2) and increases the throttle opening θ from the idling throttle opening θ_{idl} to a throttle opening θ_m, a target engine speed N_e^* corresponding to the throttle opening θ_m is set, when the driver depresses the accelerator pedal 28 further and increases the throttle opening θ a target engine speed N_e^* corresponding to the throttle opening θ_m is set, and in the automatic transmission control unit 36 feedback control is carried out so that a braking torque T_{m1} generated by the generator/motor M1 is produced and the target engine speed N_e^* is maintained. At this time, along with the feedback control, because a torque is transmitted to the output shaft 19, the output shaft speed N_o also gradually increases. When the generator/motor speed N_{m1} becomes 0, the generator/motor M1 shifts from the regenerating state to a driving state. At this time the speed line becomes the line L10.

Thereafter, as acceleration is continued, the generator/motor speed N_{m1} continues to rise while the target engine speed N_e^* is maintained unchanged. When the direct coupling clutch CL is engaged and the gearbox 16 becomes directly coupled, the rotation of the engine output shaft 12 is transmitted unchanged to the output shaft 19. As a result, the engine speed N_e, the output speed N_o and the generator/motor speed N_{m1} become equal and the speed line becomes the line L11.

A fourth preferred embodiment of the invention will now be described.

Fig. 27 is a schematic view of a starting system of a fourth preferred embodiment of the invention, and Fig. 28 is a speed line diagram of the fourth preferred embodiment of the invention.

In Fig. 27, 11 is an engine, 12 is an engine output shaft, M1 is a generator/motor, 16 is a gearbox, 18 is a starting mechanism, 19 is an output shaft of the starting mechanism 18, 21 is a transmission and 50 is a starting mechanism case.

The gearbox 16 comprises a first planetary gear unit and a second planetary gear unit; the first planetary gear unit is made up of a sun gear S_1, a pinion P_1, a ring gear R_1 and a carrier C_1 rotatably supporting the pinion P_1, and the second planetary gear unit is made up of a sun gear S_2, a pinion P_2, a ring gear R_2 and a carrier C_2 rotatably supporting the pinion P_2; the sun gear S_1 is fixed to a sun gear shaft 56, the carrier C_1 is fixed to the output shaft 19 and the ring gear R_1 is fixed to the engine output shaft 12. The sun gear S_2 is fixed to the sun gear shaft 56, the carrier C_2 is fixed to the generator/motor rotary shaft 55 and the ring gear R_2 is fixed to the output shaft 19.

The generator/motor M1 is made up of a rotor 51 and a stator 52, the rotor 51 is fixed to the generator/motor rotary shaft 55 and the stator 52 is fixed to the starting mechanism case 50.

A brake B_1 is disposed between the sun gear shaft 56 and the starting mechanism case 50, and by this brake B_1 being engaged the sun gears S_1 and S_2 can be held stationary and the gearbox 16 thereby directly coupled with a predetermined gear ratio i. In this case, because it is possible to obtain the predetermined gear ratio i in the directly coupled state of the gearbox 16, during starting it is possible to make a vehicle torque T large. Also, engagement shock when the brake B_1 is engaged can be suppressed.

In the starting system thus constructed, when to start the vehicle moving a shift lever not shown in the drawings is operated and a D range is selected, rotation at an idling speed N_{idl} (Fig. 5) is transmitted to the sun gears S_1 and S_2, but as a result of the forward clutch being engaged the inertia of the vehicle is transmitted to the output shaft 19 and the output speed N_o is 0. As a result, the speed line becomes the line L12 in the speed line diagram of Fig. 28 and the generator/motor M1 is rotated as a load and is in a regenerating state.

When the driver then depresses the accelerator pedal 28 (Fig. 2) and increases the throttle opening θ from the idling throttle opening θ_{idl} to a throttle opening θ_m, a target engine speed N_e^* corresponding to the throttle opening θ_m is set, when the driver depresses the accelerator pedal 28 further and increases the throttle opening θ a target engine speed N_e^* corresponding to the throttle opening θ_m is set, and in the automatic transmission control unit 36 feedback control is carried out so that a braking torque T_{m1} generated by the generator/motor M1 is produced and the target engine speed N_e^* is maintained. At this time, along with the feedback control, because a torque is transmitted to the output shaft 19, the output shaft speed N_o also gradually increases. When the generator/motor speed N_{m1} becomes 0, the generator/motor M1 shifts from the regenerating state to a driving state. At this time the speed line becomes the line L13.

Thereafter, as acceleration is continued, the generator/motor speed N_{m1} continues to rise while the target engine speed N_e^* is maintained unchanged. When the brake B_1 is engaged and the gearbox 16 becomes directly coupled, the rotation of the engine output shaft 12 is reduced in speed according to the gear ratio i and transmitted to the output shaft 19. As a result, the speed line becomes the line L14.

The generator/motor speed N_{m1} during regeneration is O.7 times the engine speed N_e.

A fifth preferred embodiment of the invention will now be described.

Fig. 29 is a schematic view of a starting system of a fifth preferred embodiment of the invention, and Fig. 30 is a speed line diagram of the fifth preferred embodiment of the invention.

In the figures, 11 is an engine, 12 is an engine output shaft, M1 is a generator/motor, 16 is a gearbox, 18 is a starting mechanism, 19 is an output shaft of the starting mechanism 18, 21 is a transmission and 50 is a starting mechanism case.

The gearbox 16 comprises a planetary gear unit, and this planetary gear unit is made up of a sun gear S, a pinion P, a ring gear R and a carrier C rotatably supporting the pinion P; the sun gear S is fixed to the engine output shaft 12 and the carrier C is fixed to the output shaft 19. The generator/motor M1 is made up of a rotor 51 and a stator 52, the rotor 51 is fixed to the ring gear R and the stator 52 is fixed to the starting mechanism case 50.

A direct coupling clutch CL of normally closed type is disposed between the ring gear R and the engine output shaft 12, and by this direct coupling clutch CL being engaged the ring gear R and the sun gear S can be locked together and the gearbox 16 thereby directly coupled. In this preferred embodiment the ring gear R and the sun gear S are locked together, but alternatively it may be the ring gear R and the carrier C or the carrier C and the sun gear S that are locked together.

A diaphragm spring 58 is connected to the direct coupling clutch CL, and a release bearing 59 is connected to the diaphragm spring 58. The release bearing 59 is connected to a hydraulic cylinder by way of a release fork not shown in the drawings. The diaphragm spring 58 urges the clutch o engage, and when no hydraulic pressure is being supplied to the hydraulic cylinder the direct coupling clutch CL is engaged.

As a result, the direct coupling clutch CL can be engaged and the generator/motor M1 and the engine 11 thereby connected even when the engine 11 is not running and hydraulic pressure is not being produced in the hydraulic circuit 23 (Fig. 2). Consequently the generator/motor M1 can also be used as a starter motor, and when the engine 11 is not running it is possible to start the engine 11 by driving the generator/motor M1.

When the engine 11 is driven a hydraulic pressure is produced in the hydraulic circuit 23, a hydraulic pressure is supplied to the hydraulic cylinder and the direct coupling clutch CL is released.

In this case, the speed line diagram of Fig. 30 is the same as the speed line diagram of Fig. 4.

A sixth preferred embodiment of the invention will now be described.

Fig. 31 is a schematic view of a starting system of a sixth preferred embodiment of the invention, and Fig. 32 is a speed line diagram of the sixth preferred embodiment of the invention.

In the figures, 11 is an engine, 12 is an engine output shaft, M1 is a generator/motor, 16 is a gearbox, 18 is a starting mechanism, 19 is an output shaft of the starting mechanism 18, 21 is a transmission and 50 is a starting mechanism case.

The gearbox 16 comprises a planetary gear unit, and this planetary gear unit is made up of a sun gear S, a pinion P, a ring gear R and a carrier C rotatably supporting the pinion P; the sun gear S is fixed to the engine output shaft 12 and the carrier C is fixed to the output shaft 19. The generator/motor M1 is made up of a rotor 51 and a stator 52, the rotor 51 is fixed to the ring gear R and the stator 52 is fixed to the starting mechanism case 50.

A direct coupling clutch CL is disposed between the ring gear R and the engine output shaft 12, and by this direct coupling clutch CL being engaged the ring gear R and the sun gear S can be locked together and the gearbox 16 thereby directly coupled. In this preferred embodiment the ring gear R and the sun gear S are locked together, but alternatively the ring gear R and the carrier C or the carrier C and the sun gear S may be locked together.

A one-way clutch F_1 locking only in the direction in which it rotates the engine 11 is disposed between the ring gear R and the sun gear S. Consequently the generator/motor M1 can also be used as a starter motor, and when the engine 11 is not running it is possible to start the engine 11 by driving the generator/motor M1.

In this case, the speed line diagram of Fig. 32 is the same as the speed line diagram of Fig. 4. (In this preferred embodiment, the generator/motor speed N_{m1} (Fig. 5) cannot be made higher than the engine speed N_e.)

A seventh preferred embodiment of the invention will now be described.

Fig. 33 is a time chart of a starting system of a seventh preferred embodiment of the invention. Here, a starting mechanism 18 will be discussed with reference to Fig. 3.

When the vehicle is stationary, normally the neutral range is selected, the throttle opening θ is set to an idling throttle opening θ_{idl} and the engine 11 (Fig. 2) is rotated at an idling speed N_{idl}. At this time, the rotation of the engine 11 is transmitted to the starting mechanism 18 by the engine output shaft 12 and the sun gear S is rotated at the idling speed N_{idl}.

Then, when to start the vehicle moving a shift lever not shown in the drawings is operated and the D range is selected, a forward clutch of the transmission 21 is engaged.

At this time, rotation at the idling speed N_{idl} is transmitted to the sun gear S, but as a result of the forward clutch being engaged the inertia of the vehicle is transmitted to the output shaft 19 and the output speed N_o is 0. Consequently, the generator/motor M1 is rotated as a load and is in a regenerating state.

When the driver then depresses the accelerator pedal 28 (Fig. 31) and increases the throttle opening θ from the idling throttle opening θ_{idl} to a throttle opening θ_m, a target engine speed $N_e{}^*$ corresponding to the throttle opening θ_m is set, and in the automatic transmission control unit 36 feedback control is performed so that a braking torque T_{m1} generated by the generator/motor M1 is produced and the target engine speed $N_e{}^*$ is maintained. At this time, along with the feedback control, because a torque is transmitted to the output shaft 19, the output speed N_o also gradually increases.

When at a time t11 the generator/motor speed N_{m1} becomes 0, the generator/motor M1 shifts from the regenerating state into a driving state.

Thereafter, as acceleration is continued, the generator/motor speed N_{m1} continues to rise while the target engine speed N_e^* is maintained unchanged. When at a time t12 the engine speed N_e immediately after engagement of the direct coupling clutch CL is higher than the minimum speed N_{emin} and the engine speed N_e and the output speed N_o are substantially the same, the clutch signal outputted from the automatic transmission control unit 36 to the solenoid of the solenoid valve SC is made ON and the direct coupling clutch CL is engaged. In this case, the engine speed N_e and the output speed N_o are determined to be substantially the same when the absolute value of the difference between the engine speed N_e and the output speed N_o becomes smaller than a preset engagement deviation constant β.

The output speed N_o can be calculated using the following equation:

$$N_o = (N_e - N_{m1})/i + N_{m1} \ (N_{m1} < 0)$$

In this way, when the gearbox 16 becomes directly coupled, the rotation of the engine output shaft 12 is transmitted unchanged to the output shaft 19. As a result, the engine speed N_e, the output speed N_o and the generator/motor speed N_{m1} become equal.

In this case, because the direct coupling clutch CL can be engaged when the engine speed N_e and the output speed N_o are substantially the same, engagement shock can be made small.

Next, a direct coupling clutch release control processing subroutine will be described.

Fig. 34 is a flow chart of a direct coupling clutch release control processing subroutine of the seventh preferred embodiment of the invention, Fig. 35 is a time chart of the direct coupling clutch release control processing of the seventh preferred embodiment of the invention and Fig. 36 is a deviation constant map of the seventh preferred embodiment of the invention.

Step S11-1: It is determined whether or not a flag LFSC indicating the engaged/disengaged state of the direct coupling clutch CL (Fig. 3) is 0. When the flag LFSC is 0 processing proceeds to Step S11-201, and when the flag LFSC is not 0 processing proceeds to Step S11-8 (Fig. 10). When the direct coupling clutch CL is not in an engaging transient state the flag LFSC is 0 and when the direct coupling clutch CL is in a releasing transient state the flag LFSC is A.

Step S11-201: A target engine speed N_e^* is set.

Step S11-202: A direct coupling clutch CL release deviation constant β' is read from the deviation constant map of Fig. 36 and is set. As shown in Fig. 36, when the throttle opening θ becomes large, because the engine torque is amply high, engine stalling does not occur even when the direct coupling clutch CL is engaged. Accordingly, when the throttle opening θ is large the release deviation constant β' and the engagement deviation constant β are made large. As a result, the direct coupling clutch CL can be engaged quickly and released slowly.

Also, the release deviation constant β' and the engagement deviation constant β are made small values when the charge state of the main battery 47 monitored by the remaining charge detecting device 48 (Fig. 2) is good and are made large values when it is poor. As a result, because when the charge state of the main battery 47 is good the direct coupling clutch CL is engaged after the difference between the target engine speed N_e^* and the output speed N_o becomes small, the engagement shock can be made small. When on the other hand the charge state of the main battery 47 is poor, the amount of electricity consumed by the generator/motor M1 can be made small.

When the engine torque produced by the engine 11 is large, if the generator/motor M1 is made to follow the engine 11 not only does the generator/motor M1 have to be large but also the capacity of the main battery 47 has to be made large in correspondence with the engine torque. In that case, by making the release deviation constant β' and the engagement deviation constant β large, the generator/motor M1 can be made compact and the capacity of the main battery 47 can be made small.

Step S11-203: It is determined whether or not the difference between the target engine speed N_e^* and the output speed N_o is greater than the release deviation constant β'. When the difference between the target engine speed N_e^* and the output speed N_o is greater than the release deviation constant β' processing proceeds to Step S11-5, and when the difference between the target engine speed N_e^* and the output speed N_o is less than the release deviation constant β' processing proceeds to Step S11-204.

Step S11-204: The target engine speed N_e^* is reset.

Step S11-5: The clutch signal is made OFF.

Step S11-6: Because even when the clutch signal is made OFF the direct coupling clutch CL is not released immediately, the flag LFSC is made A and a releasing transient state is monitored.

Step S11-7: To make the shift of the engine speed N_e to the target engine speed N_e^* smooth, an initial torque T_{mi} of the generator/motor M1 is set.

Next, a direct coupling clutch engagement control processing subroutine will be described.

Fig. 37 is a flow chart of a direct coupling clutch engagement control processing subroutine of the seventh preferred embodiment of the invention.

Step S18-1: It is determined whether or not the flag LFSC is 0. When the flag LFSC is 0 processing proceeds to Step S18-201, and when the flag LFSC is not 0 processing proceeds to Step S18-6 (Fig. 17).

Step S18-201: It is determined whether or not the output speed N_o is higher than the minimum speed N_{emin}. When the output speed N_o is higher than the minimum speed N_{emin} processing proceeds to Step S18-202, and when the output speed N_o is less than the minimum speed N_{emin} processing returns.

Step S18-202: The engagement deviation constant β of the direct coupling clutch CL (Fig. 5) is read from the deviation constant map of Fig. 36 and is set.

Step S18-203: Calculating means not shown in the drawings compares the absolute value of the difference between the engine speed N_e and the output speed N_o with the engagement deviation constant β and determines whether or not the absolute value of the difference between the engine speed N_e and the output speed N_o is smaller than the engagement deviation constant β. When the absolute value of the difference between the engine speed N_e and the output speed N_o is smaller than the engagement deviation constant β processing proceeds to Step S18-4, and when the absolute value of the difference between the engine speed N_e and the output speed N_o is above the engagement deviation constant β processing returns. In this preferred embodiment the absolute value of the difference between the engine speed N_e and the output speed N_o is compared to the engagement deviation constant β, but alternatively for example the absolute value of the difference between the generator/motor speed N_{m1} and the engine speed N_e can be compared to the engagement deviation constant β. Also, a ratio can be used instead of the difference.

Step S18-4: The clutch signal is made ON.

Step S18-5: The flag LFSC is set to 1.

An eighth preferred embodiment of the invention will now be described.

Fig. 38 is a time chart of a starting system of an eighth preferred embodiment of the invention. Here, a starting mechanism 18 will be discussed with reference to Fig. 3.

When the vehicle is stationary, normally the neutral range is selected, the throttle opening θ is set to an idling throttle opening θ_{idl} and the engine 11 (Fig. 2) is rotated at an idling speed N_{idl}. At this time, the rotation of the engine 11 is transmitted to the starting mechanism 18 by the engine output shaft 12 and the sun gear S is rotated at the idling speed N_{idl}.

Then, when to start the vehicle moving a shift lever not shown in the drawings is operated and the D range is selected, a forward clutch of the transmission 21 is engaged.

At this time, rotation at the idling speed N_{idl} is transmitted to the sun gear S, but as a result of the forward clutch being engaged the inertia of the vehicle is transmitted to the output shaft 19 and the output speed N_o is 0. Consequently, the generator/motor M1 is rotated as a load and is in a regenerating state.

When the driver then depresses the accelerator pedal 28 and increases the throttle opening θ from the idling throttle opening θ_{idl} to a throttle opening θ_m, a target engine speed N_e^* corresponding to the throttle opening θ_m is set, and in the automatic transmission control unit 36 feedback control is performed so that a braking torque T_{m1} generated by the generator/motor M1 is produced and the target engine speed N_e^* is maintained. At this time, along with the feedback control, because a torque is transmitted to the output shaft 19, the output speed N_o also gradually increases.

When at a time t21 the generator/motor speed N_{m1} becomes 0, the generator/motor M1 shifts from the regenerating state into a driving state.

Thereafter, as acceleration is continued, the generator/motor speed N_{m1} continues to rise while the target engine speed N_e^* is maintained unchanged. Then, when at a time t22 the engine speed N_e immediately after engagement of the direct coupling clutch CL is higher than the minimum speed N_{emin} and an electrical power W_+ obtained by regeneration and an electrical power W_- consumed by the generator/motor M1 become substantially equal, the clutch signal outputted from the automatic transmission control unit 36 to the solenoid of the solenoid valve SC is made ON and the direct coupling clutch CL is engaged.

In this way, when the gearbox 16 becomes directly coupled, the rotation of the engine output shaft 12 is transmitted unchanged to the output shaft 19. As a result, the engine speed N_e, the output speed N_o and the generator/motor speed N_{m1} become equal.

In this case, because only the power W_+ obtained by regeneration with the generator/motor M1 is consumed in driving the generator/motor M1, the capacity of the main battery 47 can be made small.

Next, a direct coupling clutch engagement control processing subroutine will be described.

Fig. 39 is a flow chart of a direct coupling clutch engagement control processing subroutine of the eighth preferred embodiment of the invention.

Step S18-1: It is determined whether or not the flag LFSC is 0. When the flag LFSC is 0 processing proceeds to Step S18-301, and when the flag LFSC is not 0 processing proceeds to Step S18-6 (Fig. 17).

Step S18-301: It is determined whether or not the output speed N_o is higher than the minimum speed N_{emin}. When the output speed N_o is higher than the minimum speed N_{emin} processing proceeds to Step S18-302, and when the output speed N_o is less than the minimum speed N_{emin} processing returns.

Step S18-302: The difference between the power W_+ obtained by regeneration and the power W_- consumed in driving generator/motor M1 is compared to a set value α; when the difference is smaller than the set value α processing proceeds to Step S18-4, and when the difference is greater than the set value α processing returns.

Step S18-4: The clutch signal is made ON.

Step S18-5: The flag LFSC is set to 1.

A ninth preferred embodiment of the invention will now be described.

Fig. 40 is a schematic view of a starting system of a ninth preferred embodiment of the invention.

In Fig. 40, 11 is an engine (E/G), 12 is an engine output shaft by which rotation generated by the engine 11 is transmitted and M2 is a generator serving as an electric rotary device. The generator M2 generates a braking torque T_{m2} and applies this braking torque T_{m2} to the engine output shaft 12 as a reaction torque.

A resolver 15 detects magnetic pole positions of the generator M2; a gearbox 16 is connected to the engine output shaft 12; 18 is a starting mechanism made up of the resolver 15, the generator M2 and the gearbox 16; and 19 is an output shaft for transmitting rotation generated by the starting mechanism 18 to a transmission 21. In this preferred embodiment the transmission 21 is an automatic transmission (A/T), but it may alternatively be a manual transmission.

The gearbox 16 has a speed-reducing gear mechanism not shown in the drawings, for example a planetary gear unit, and has a clutch not shown in the drawings which can selectively engage and disengage the elements of the planetary gear unit. This clutch is engaged and disengaged by a hydraulic servo not shown in the drawings of a hydraulic circuit 23. The hydraulic circuit 23 has a solenoid valve SC for selectively supplying oil to the hydraulic servo.

In this preferred embodiment, because the transmission 21 is an automatic transmission, the hydraulic circuit 23 has solenoid valves S1, S2 for selecting the gears of the transmission 21.

When a gear is selected by the hydraulic circuit 23, a rotation corresponding to that gear is transmitted via a drive shaft 24 to the vehicle driving wheels 25.

By depressing an accelerator pedal 28 it is possible to change the throttle opening as an engine load. The throttle opening is detected by a throttle sensor 29 linked to the accelerator pedal 28. An engine speed sensor 30 is disposed facing the engine output shaft 12 and detects the engine speed, an output speed sensor 31 is disposed facing the output shaft 19 and detects the output speed of the starting mechanism 18, a shift position switch 33 is linked to a shift lever not shown in the drawings and detects a range and gear selected by said shift lever, and a vehicle speed sensor 34 is disposed facing the drive shaft 24 and detects a vehicle speed correspondent value V.

In this preferred embodiment, the engine speed sensor 30 is disposed facing the engine output shaft 12 and detects the speed of the engine output shaft 12; however, alternatively it is possible to use a signal from an ignition system instead of the speed of the engine output shaft 12. Also, although in this preferred embodiment the output speed sensor 31 is disposed facing the output shaft 19 and detects the speed of the output shaft 19, the speed of the input shaft of the transmission 21 can alternatively be detected instead of the speed of the output shaft 19.

In an automatic transmission control unit 36, a starting output and a gear-change output are generated based on the throttle opening detected by the throttle sensor 29, the vehicle speed detected by the vehicle speed sensor 34 and the range and gear detected by the shift position switch 33; a clutch signal corresponding to the starting output is outputted to the solenoid of the solenoid valve SC and solenoid signals corresponding to the gear-change output are outputted to the solenoids of the solenoid valves S1, S2.

The hydraulic circuit 23 supplies hydraulic pressure to the hydraulic servo based on the clutch signal and the solenoid signals received by the solenoids, selects gears and directly couples the starting mechanism 18.

An ignition switch 39 produces a start signal when a driver turns an ignition key, a brake sensor 41 detects a brake stroke or a brake fluid pressure when the driver depresses a brake pedal 42 and thereby detects a braking force called for by the driver, and a fuel injection control unit 44 (EFIECU) receives a neutral signal generated by the automatic transmission control unit 36 and reduces a fuel injection quantity in the engine 11.

An output control unit 46 drives the generator M2 and thereby produces a braking torque T_{m2} required to start the vehicle moving; the main battery 47 serves as an electricity storing device for supplying current for driving the generator M2 and receiving and storing electricity obtained by regeneration; a remaining charge detecting device 48 monitors the charge state of the main battery 47 based on voltage and current integrated values or the like, and a rectifier 49 rectifies a 3-phase alternating current generated by the generator M2 into a direct current.

An operation signal SG1 is outputted from the automatic transmission control unit 36 to the output control unit 46, and this operation signal SG1 is made up of an ON/OFF signal of a switching device for controlling the current supplied to the generator M2 and a chopper duty signal and the like. An operation signal SG2 is outputted from the rectifier 49 to the automatic transmission control unit 36, and this operation signal SG2 is used as a current monitor signal for conducting feedback control in the automatic transmission control unit 36.

The operation of the starting system thus constructed will be now described.

Fig. 41 is a time chart of the starting system of the ninth preferred embodiment of the invention. Here, the starting mechanism 18 will be discussed with reference to Fig. 3.

When the vehicle is stationary, normally the neutral range is selected, the throttle opening θ is set to an idling throttle opening θ_{idl} and the engine 11 (Fig. 2) is rotated at an idling speed N_{idl}. At this time, the rotation of the engine 11 is

transmitted to the starting mechanism 18 by the engine output shaft 12 and the sun gear S is rotated at the idling speed N_{idl}.

Then, when to start the vehicle moving a shift lever not shown in the drawings is operated and the D range is selected, a forward clutch, not shown in the drawings, of the transmission 21 is engaged.

At this time, rotation at the idling speed N_{idl} is transmitted to the sun gear S, but as a result of the forward clutch being engaged the inertia of the vehicle is transmitted to the output shaft 19 and the output speed N_o is 0. Consequently, the generator M2 (Fig. 40) is rotated as a load and is in a regenerating state while generating a braking torque T_{m2}.

When the driver then depresses the accelerator pedal 28 and increases the throttle opening θ from the idling throttle opening θ_{idl} to a throttle opening θ_m, a target engine speed N_e^* corresponding to the throttle opening θ_m is set, and in the automatic transmission control unit 36 feedback control is performed so that a braking torque T_{m2} generated by the generator M2 is produced and the target engine speed N_e^* is maintained. At this time, along with the feedback control, because a torque is transmitted to the output shaft 19, the output speed N_o also gradually increases.

When at a time t31 the generator speed N_{m2} becomes substantially 0, the clutch signal outputted from the automatic transmission control unit 36 to the solenoid of the solenoid valve SC is made ON and the direct coupling clutch CL is engaged.

In this case, it is determined that the generator speed N_{m2} has become substantially 0 when the absolute value of the generator speed N_{m2} becomes smaller than γ. The generator speed N_{m2} can be calculated using the following equation:

$$N_{m2} = N_e - (N_e - N_o) i/(i-1) \quad (N_{m2} < 0)$$

The generator speed N_{m2} can also be directly detected.

In this way, when the gearbox 16 becomes directly coupled, the rotation of the engine output shaft 12 is transmitted unchanged to the output shaft 19. As a result, the engine speed N_e, the output speed N_o and the generator speed N_{m2} become equal.

In this preferred embodiment, because there is only the regeneration state and there is no driving state, the output control unit 46 (Fig. 40) can be simplified.

Next, a direct coupling clutch engagement control processing subroutine will be described.

Fig. 42 is a flow chart of a direct coupling clutch engagement control processing subroutine of the ninth preferred embodiment of the invention.

Step S18-1: It is determined whether or not the flag LFSC is 0. When the flag LFSC is 0 processing proceeds to Step S18-401, and when the flag LFSC is not 0 processing proceeds to Step S18-6 (Fig. 17).

Step S18-401: It is determined whether or not the output speed N_o is higher than the minimum speed N_{emin}. When the output speed N_o is higher than the minimum speed N_{emin} processing proceeds to Step S18-402, and when the output speed N_o is lower than minimum speed N_{emin} processing returns.

Step S18-402: It is determined whether or not the absolute value of the generator speed N_{m2} is smaller than γ. When the absolute value of the generator speed N_{m2} is smaller than γ processing proceeds to Step S18-4, and when the absolute value of the generator speed N_{m2} is above γ processing returns.

Step S18-4: The clutch signal is made ON.

Step S18-5: The flag LFSC is set to 1.

A tenth preferred embodiment of the invention will now be described.

Fig. 43 is a time chart of a starting system of a tenth preferred embodiment of the invention, and Fig. 44 is a flow chart of a direct coupling clutch engagement control processing subroutine of the tenth preferred embodiment of the invention.

In this case, a regeneration current I_+ produced while a generator M2 (Fig. 40) is being rotated as a load is monitored and the direct coupling clutch CL is engaged when the regeneration current I_+ has become smaller than a set value δ. When a separately excited generator in which permanent magnets are not used is used as the generator M2, when the throttle opening θ is large or when the engine torque is large the set value δ is made large.

Step S18-1: It is determined whether or not the flag LFSC is 0. When the flag LFSC is 0 processing proceeds to Step S18-501, and when the flag LFSC is not 0 processing proceeds to Step S18-6 (Fig. 17).

Step S18-501: It is determined whether or not the output speed N_o is higher than the minimum speed N_{emin}. When the output speed N_o is higher than the minimum speed N_{emin} processing proceeds to Step S18-502, and when the output speed N_o is less than minimum speed N_{emin} processing returns.

Step S18-502: It is determined whether or not the regeneration current I_+ is smaller than the set value δ. When the regeneration current I_+ is smaller than the set value δ processing proceeds to Step S18-4, and when the regeneration current I_+ is above the set value δ processing returns.

Step S18-4: The clutch signal is made ON.

Step S18-5: The flag LFSC is set to 1.

An eleventh preferred embodiment of the invention will now be described.

Fig. 45 is a time chart of starting system of an eleventh preferred embodiment of the invention.

In this case, when the starting output is outputted, an engaging determination starting timer not shown in the drawings commences timing, and when a set time has elapsed the direct coupling clutch CL (Fig. 3) is put into a semi-engaged state by slip control or duty control. As a result, the engine speed N_e gradually falls from the target engine speed N_e^*.

Thereafter, feedback control is so carried out that the engine speed N_e does not become smaller than a set value for engaging N_{el}, and when the output speed N_o becomes higher than the engine speed N_e the direct coupling clutch CL is completely engaged.

In this way, because it only has to put the direct coupling clutch CL into a semi-engaged state and perform feedback control of the engine speed N_e, the output control unit 46 can be simplified.

The invention is not limited to the preferred embodiments described above and various changes can be made thereto within the scope of the invention.

Claims

1. A starting system comprising:

   a gearbox, having at least a first gear element connected to an output shaft of an engine, a second gear element connected to a driving wheel of a vehicle and a third gear element, for by applying a braking torque to the third gear element reducing the speed of a rotation inputted from the first gear element and outputting it to the second gear element;

   an engaging element connected to any of the gear elements for being selectively engaged and mechanically connecting the output shaft of the engine to the driving wheel;

   an electric rotary device connected to the third gear element;

   an accumulator;

   engine load detecting means for detecting an engine load;

   speed detecting means for detecting the speed of at least one of the gear elements of the gearbox and outputting a speed signal; and

   a control unit comprising electric rotary device controlling means for setting a target speed of the first gear element based on the engine load and bringing the speed of the first gear element obtained from the speed signal to the target speed by driving the electric rotary device and causing the electric rotary device to generate a braking torque and engaging element engaging and disengaging means for comparing the speed of a gear element other than the first gear element obtained from the speed signal with set values for engaging and disengaging and engaging and disengaging the engaging element based on the comparison results.

2. A starting system according to claim 1 wherein:

   the set values for engaging and disengaging are set in correspondence with the engine load and are higher the greater the engine load is.

3. A starting system according to claim 1 or 2 further comprising:

   operating means for selecting a driving state and a non-driving state of the vehicle;

   vehicle speed detecting means for detecting the speed of the vehicle,

   wherein the electric rotary device controlling means is provided with braking torque setting up means for driving the electric rotary device and setting up a braking torque when a driving state of the vehicle is selected by means of the operating means and the engine load detected by the engine load detecting means is substantially zero and the vehicle speed detected by the vehicle speed detecting means is below a set value.

4. A system according to claim 1, 2, or 3 further comprising:

   brake detecting means for detecting depression of a brake pedal; and

   vehicle speed detecting means for detecting the speed of the vehicle,

   wherein the electric rotary device controlling means makes the braking torque generated by the electric rotary device zero when depression of the brake pedal is detected by the brake detecting means, the engine load detected by the engine load detecting means is substantially zero and the vehicle speed detected by the vehicle speed detecting means is below a set value.

5. A system according to any of claims 1 to 4 wherein:

   when the engine load detected by the engine load detecting means is substantially zero and the speed of a gear element other than the first gear element obtained from the speed signal is below a set value for release, the engaging element engaging and disengaging means releases the engaging element and the electric rotary device controlling means keeps the speed of a gear element other than the first gear element obtained from the speed signal in a high electricity generation efficiency region.

6. A system according to any of claims 1 to 4 wherein:
when the engine load detected by the engine load detecting means is substantially zero and the speed of a gear element other than the first gear element obtained from the speed signal is below a set value for release, the engaging element engaging and disengaging means releases the engaging element and the electric rotary device controlling means keeps the speed of the first gear element obtained from the speed signal above a set value.

7. A system according to any of claims 1 to 6 further comprising:
a remaining charge detecting device for monitoring the charge state of the accumulator,
wherein when the engine load detected by the engine load detecting means is substantially zero and the speed of a gear element other than the first gear element obtained from the speed signal is below a first set value for release and the charge state of the accumulator monitored by the remaining charge detecting device is poor the engaging element engaging and disengaging means releases the engaging element and the electric rotary device controlling means keeps the speed of a gear element other than the first gear element obtained from the speed signal in a high electricity generation efficiency region, and when the engine load detected by the engine load detecting means is substantially zero and the speed of a gear element other than the first gear element obtained from the speed signal is below a second set value for release and the charge state of the accumulator monitored by the remaining charge detecting device is good the engaging element engaging and disengaging means releases the engaging element and the electric rotary device controlling means keeps the speed of the first gear element obtained from the speed signal above a set value.

8. A system according to any of claims 1 to 7 further comprising:
calculating means for calculating a speed difference or a speed ratio of speeds of two gear elements detected by the speed detecting means,
wherein when the speed of a gear element other than the first gear element obtained from the speed signal is above a set value for engaging and the speed difference or speed ratio calculated by the calculating means is smaller than a preset deviation constant, the engaging element engaging and disengaging means engages the engaging element.

9. A starting system according to claim 8 wherein:
the deviation constant is set in correspondence with the engine load and is larger the larger the engine load is.

10. A system according to claim 8 or 9 further comprising:
a remaining charge detecting device for monitoring the charge state of the accumulator,
wherein the electric rotary device is a generator/motor and the preset deviation constant is set to a small value when the charge state monitored by the remaining charge detecting device is good and to a large value when the charge state is poor.

11. A system according to any of claims 1 to 10 wherein:
when the speed of a gear element other than the first gear element obtained from the speed signal is above a set value for engaging and the absolute value of the speed of a gear element other than the first gear element obtained from the speed signal is substantially zero, the engaging element engaging and disengaging means engages the engaging element.

12. A system according to any of claims 1 to 10 wherein:
when the speed of a gear element other than the first gear element obtained from the speed signal is above a set value for engaging and the absolute value of the speed of a gear element other than the first gear element obtained from the speed signal is smaller than a set value set in correspondence with the engine load the engaging element engaging and disengaging means engages the engaging element.

13. A system according to any of claims 1 to 12 further comprising:
regenerated power detecting means for detecting a regenerated power generated by the electric rotary device,
wherein when the speed of a gear element other than the first gear element obtained from the speed signal is above a set value for engaging and the regenerated power detected by the regenerated power detecting means is smaller than a set value the engaging element engaging and disengaging means engages the engaging element.

14. A system according to any of claims 1 to 13 wherein:
the electric rotary device is a generator.

15. A system according to claims 1 to 13 wherein:
the electric rotary device is a generator/motor.

16. A starting system according to claim 15 wherein:
when engaging of the engaging element by the engaging element engaging and disengaging means has been completed the electric rotary device controlling means reduces a braking torque generated by the generator/motor by a set rate.

17. A system according to claim 15 or 16 wherein:
from the start of engaging of the engaging element by the engaging element engaging and disengaging means to the completion thereof the electric rotary device controlling means reduces the braking torque of the generator/motor.

18. A system according to claim 15, 16, or 17 further comprising:
a one-way clutch for transmitting a rotation of the generator/motor to the output shaft of the engine.

19. A system according to claim 15, 16, or 17 wherein:
the engaging element is a clutch of normally closed type and transmits a rotation of the generator/motor to the output shaft of the engine.

20. A system according to any of claims 15 to 19 wherein:
when the difference between a power obtained from regeneration by the generator/motor and a power consumed in driving the generator/motor is smaller than a set value and the speed of a gear element other than the first gear element obtained from the speed signal is larger than a set value for engaging, the engaging element engaging and disengaging means engages the engaging element.

21. A starting system comprising:
a gearbox, having at least a first gear element connected to an output shaft of an engine, a second gear element connected to a driving wheel of a vehicle and a third gear element, for by applying a braking torque to the third gear element reducing the speed of a rotation inputted from the first gear element and outputting it to the second gear element;
an engaging element connected to any of the gear elements for being selectively engaged and mechanically connecting the output shaft of the engine to the driving wheel;
an electric rotary device connected to the third gear element;
an accumulator;
engine load detecting means for detecting an engine load;
speed detecting means for detecting the speed of at least one of the gear elements of the gearbox and outputting a speed signal; and
a control unit comprising electric rotary device controlling means for setting a target speed of the first gear element based on the engine load and bringing the speed of the first gear element obtained from the speed signal to a target speed by driving the electric rotary device and causing the electric rotary device to generate a braking torque and engaging element engaging and disengaging means for comparing the speed of the first gear element when the engaging element has been engaged with a set value for disengaging and disengaging the engaging element based on the comparison results.

FIG. 1

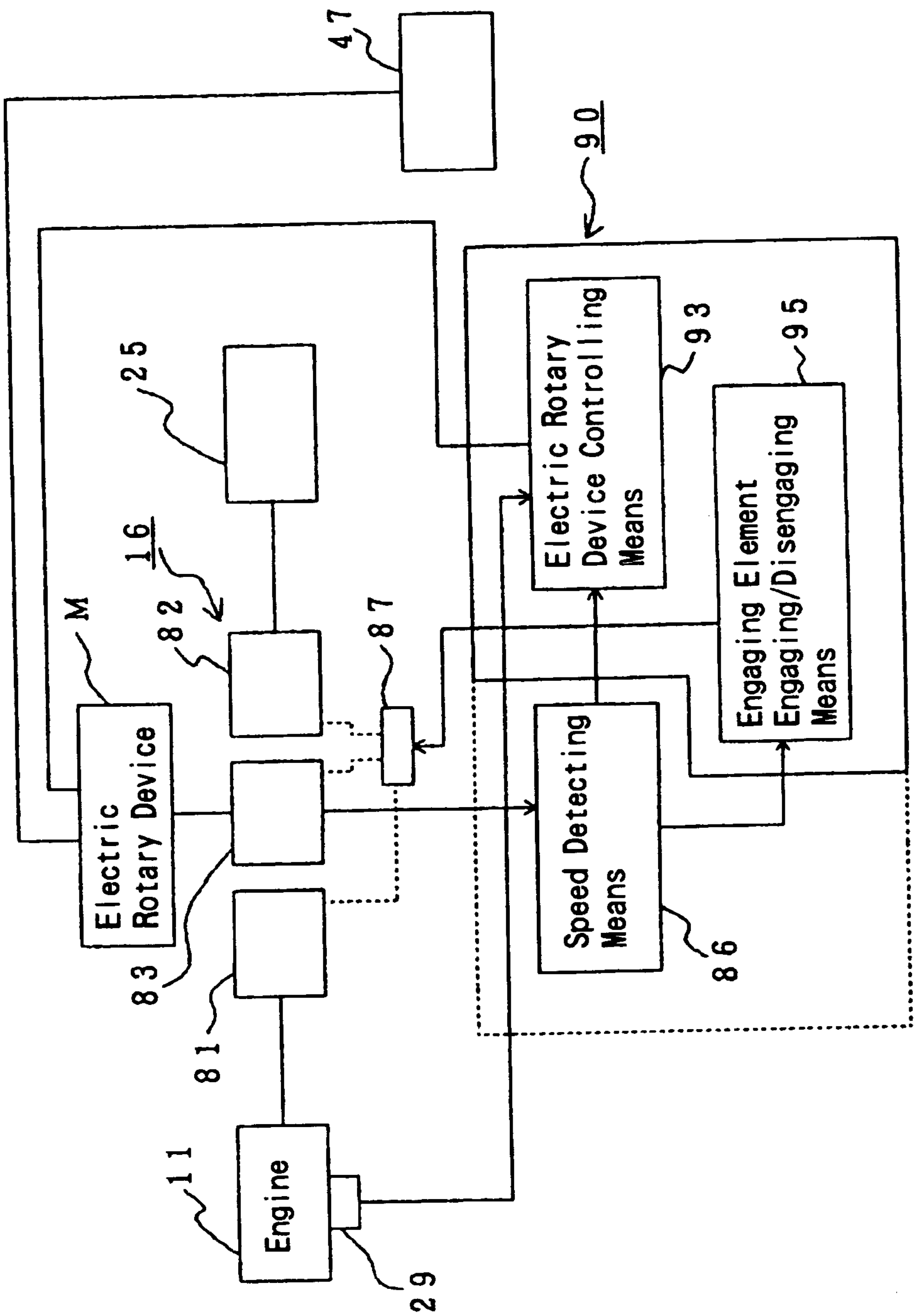
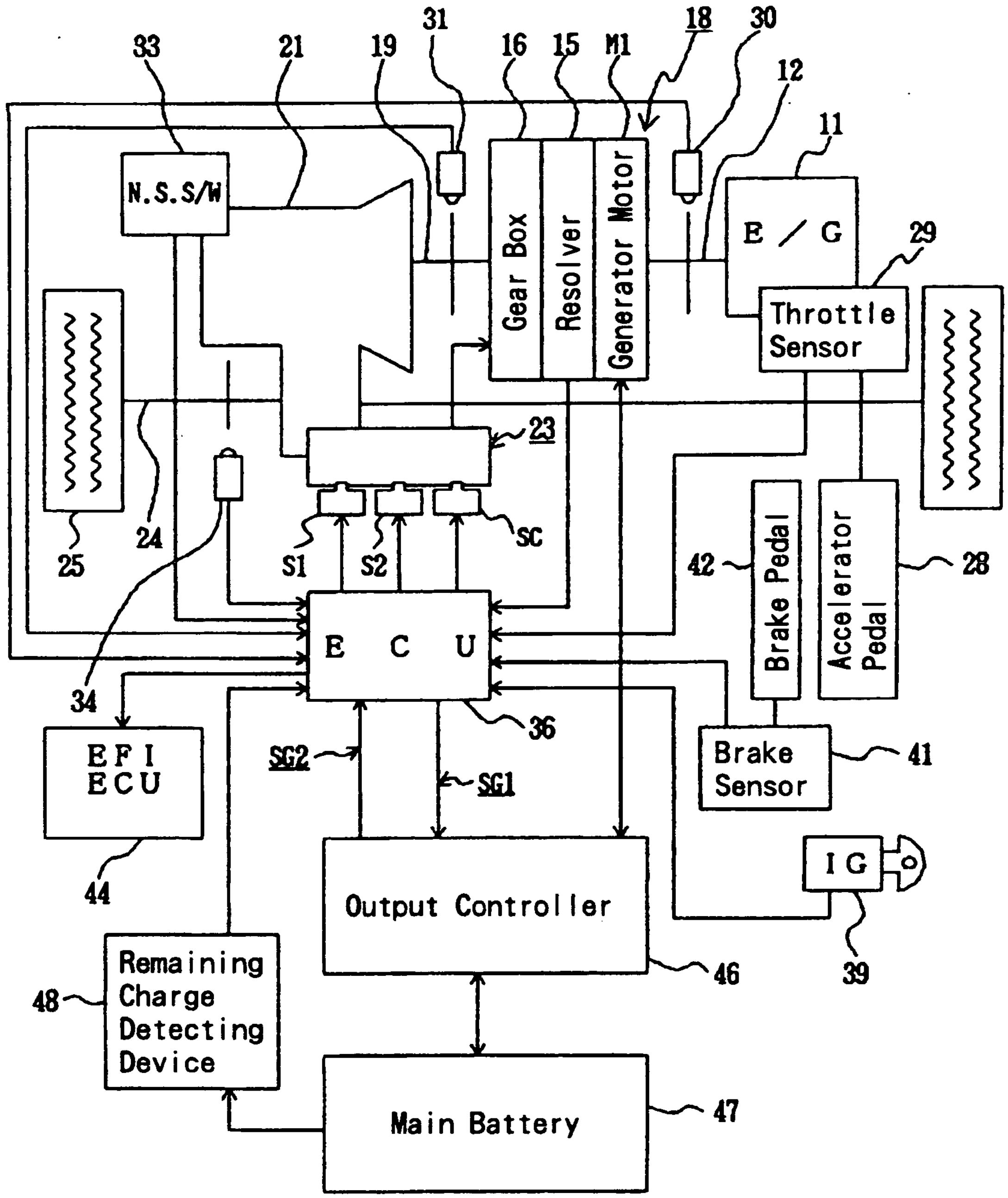

47
90
25
Electric Rotary Device Controlling Means
93
95
Engaging Element Engaging/Disengaging Means
M
82
16
87
Electric Rotary Device
Speed Detecting Means
86
83
81
11
Engine
29

FIG. 2



33
21
19
31
16
15
M1
18
30
12
11
N.S.S/W
Gear Box
Resolver
Generator Motor
E / G
29
Throttle Sensor
23
25
24
S1
S2
SC
42
Brake Pedal
Accelerator Pedal
28
E C U
34
36
EFI ECU
SG2
SG1
Brake Sensor
41
44
IG
Output Controller
46
39
48
Remaining Charge Detecting Device
Main Battery
47

FIG. 3

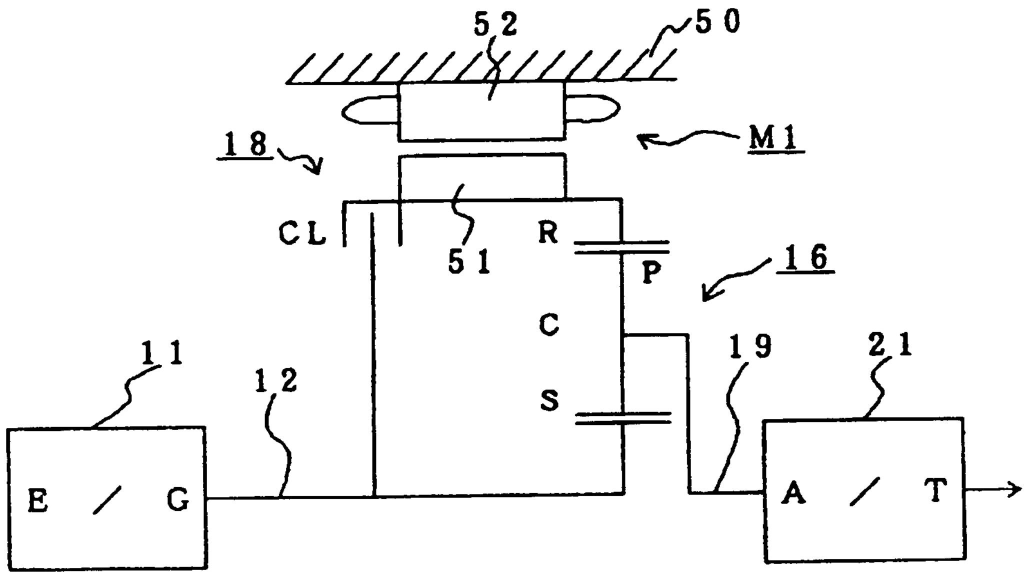


FIG. 4

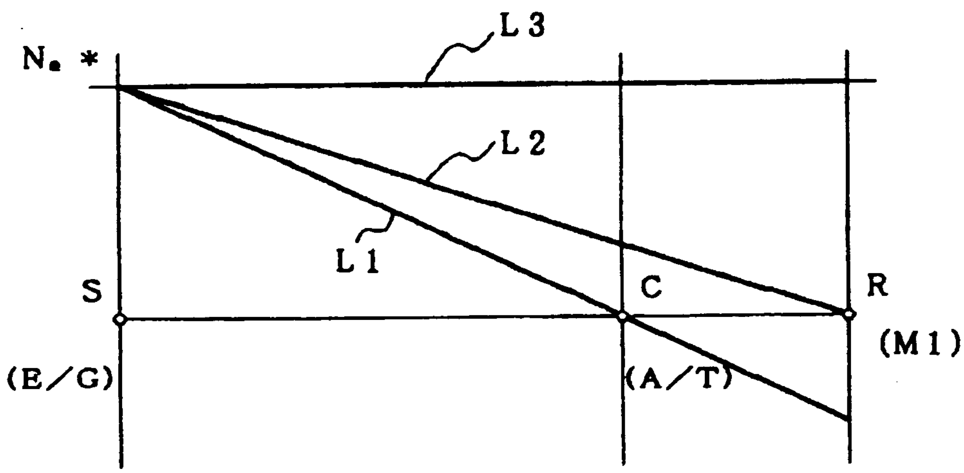


FIG. 5

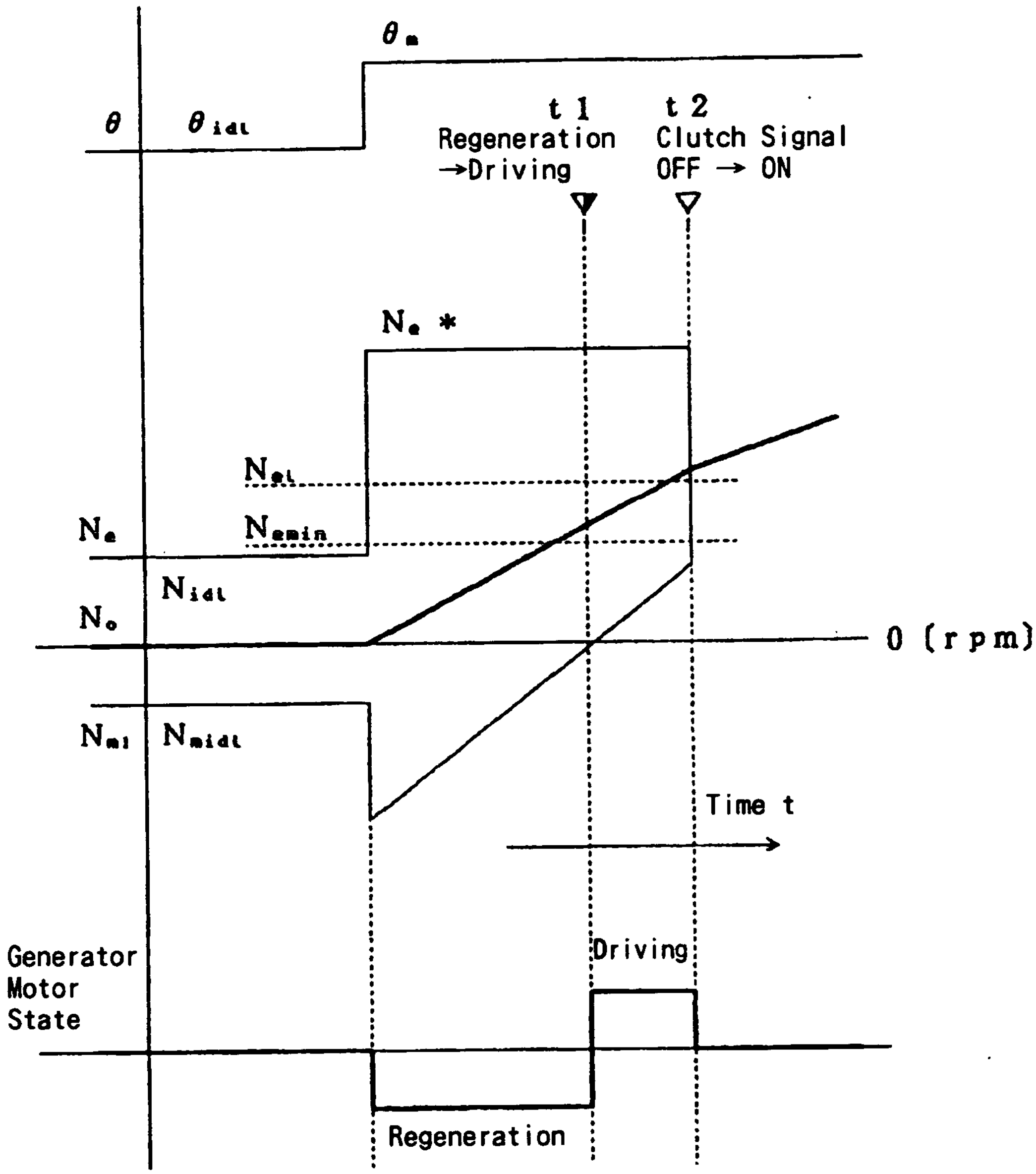

θm
θ
θidl
t 1
Regeneration
→Driving
t 2
Clutch Signal
OFF → ON
Ne *
Nel
Ne
Nemin
Nidl
No
0 (rpm)
Nm1
Nmidl
Time t
Generator
Motor
State
Driving
Regeneration

FIG. 6

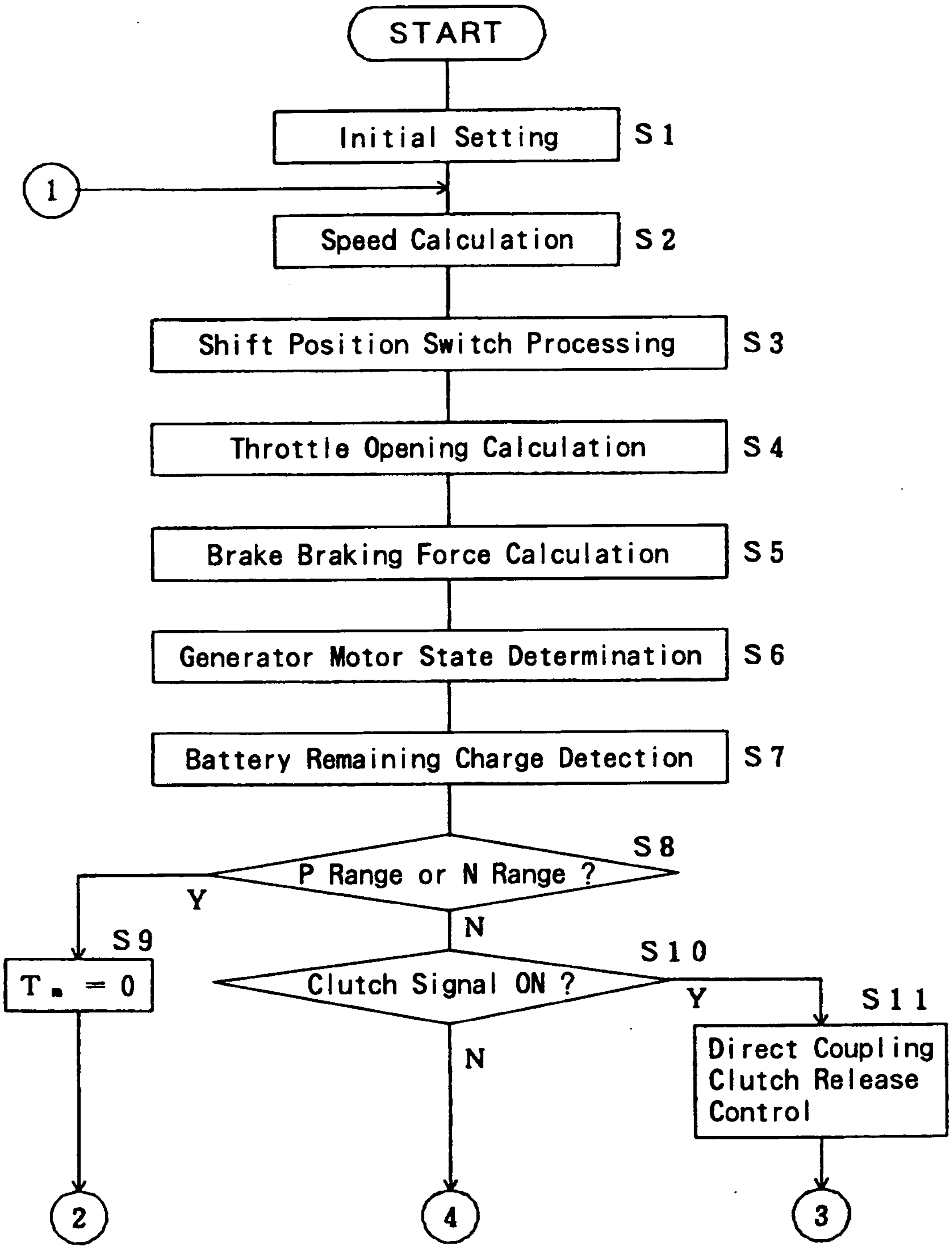

START
Initial Setting
S1
1
Speed Calculation
S2
Shift Position Switch Processing
S3
Throttle Opening Calculation
S4
Brake Braking Force Calculation
S5
Generator Motor State Determination
S6
Battery Remaining Charge Detection
S7
P Range or N Range ?
S8
Y
N
S9
$T_m = 0$
Clutch Signal ON ?
S10
Y
N
S11
Direct Coupling Clutch Release Control
2
4
3

FIG. 7

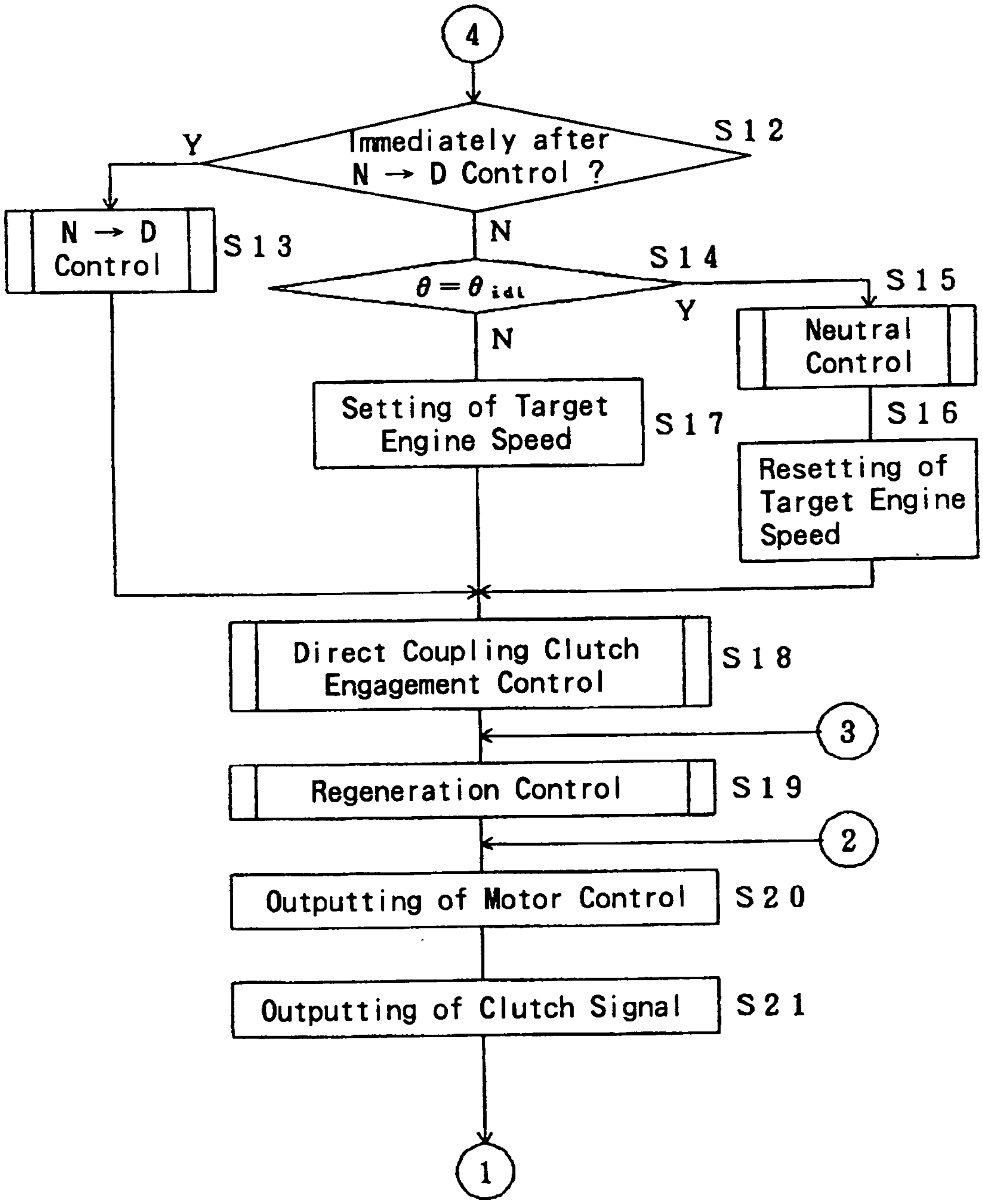

4
Immediately after N → D Control ?
S12
Y
N
N → D Control
S13
θ = θ idl
S14
Y
N
S15
Neutral Control
S16
Setting of Target Engine Speed
S17
Resetting of Target Engine Speed
Direct Coupling Clutch Engagement Control
S18
3
Regeneration Control
S19
2
Outputting of Motor Control
S20
Outputting of Clutch Signal
S21
1

FIG. 8

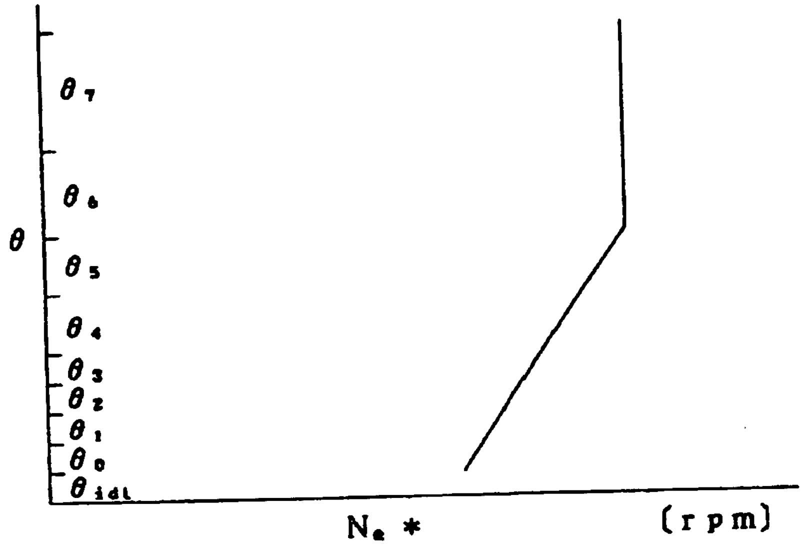

θ
θ7
θ6
θ5
θ4
θ3
θ2
θ1
θ0
θidl
Ne *
(rpm)

FIG. 9

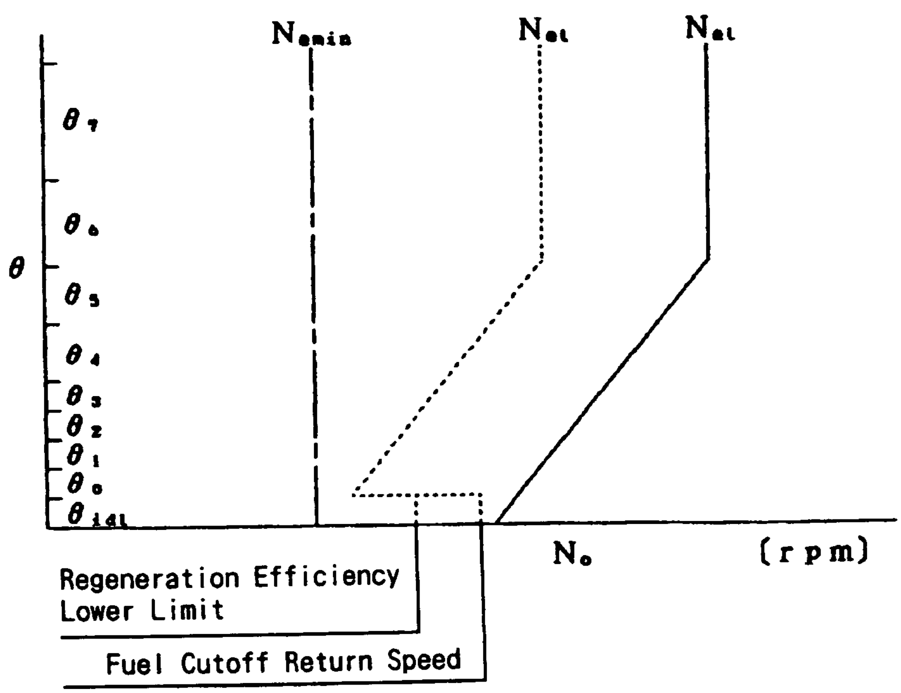

Nemin
Nel
Nel
θ
θ7
θ6
θ5
θ4
θ3
θ2
θ1
θ0
θidl
Ne
(rpm)
Regeneration Efficiency
Lower Limit
Fuel Cutoff Return Speed

FIG. 10

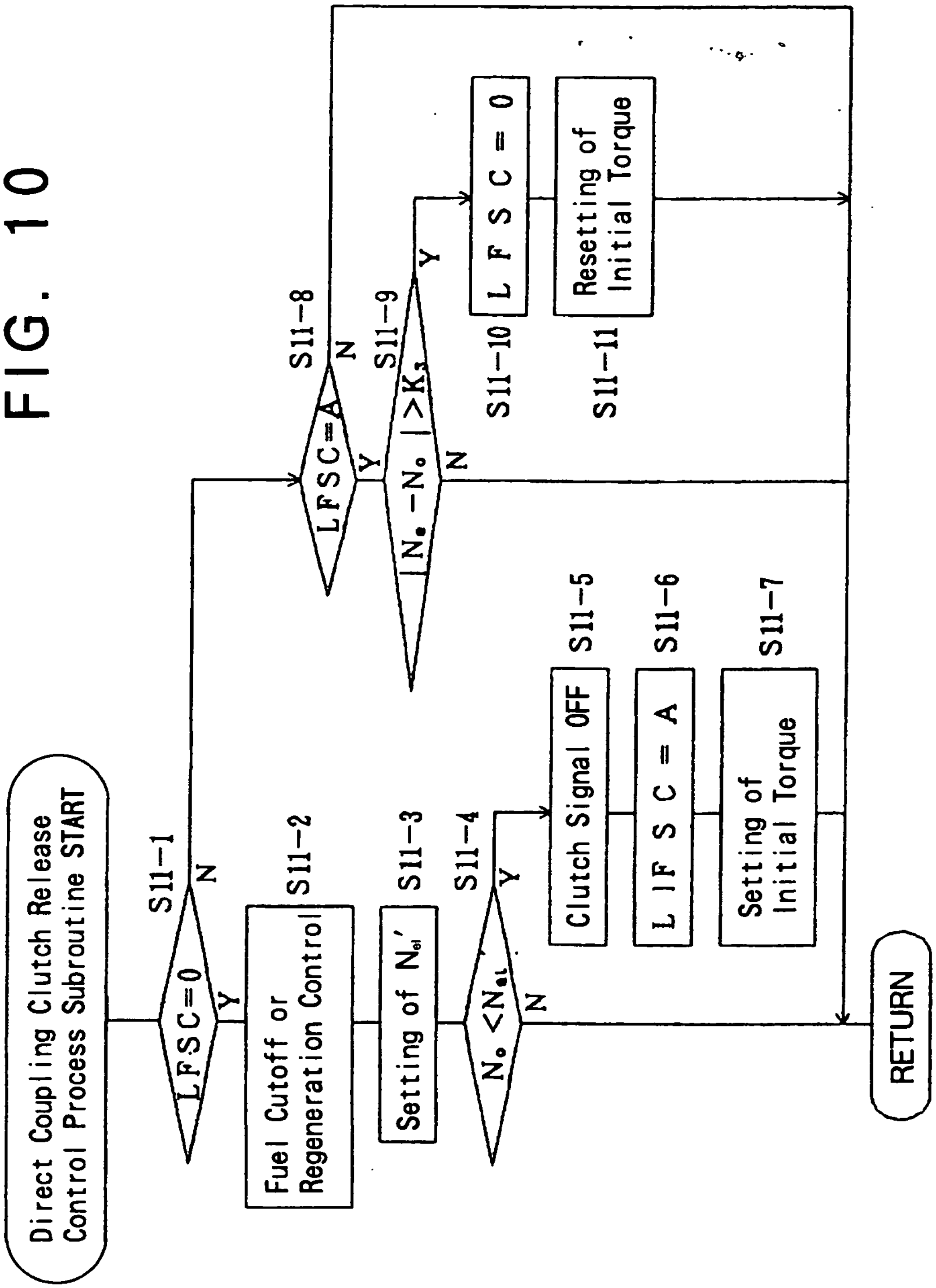
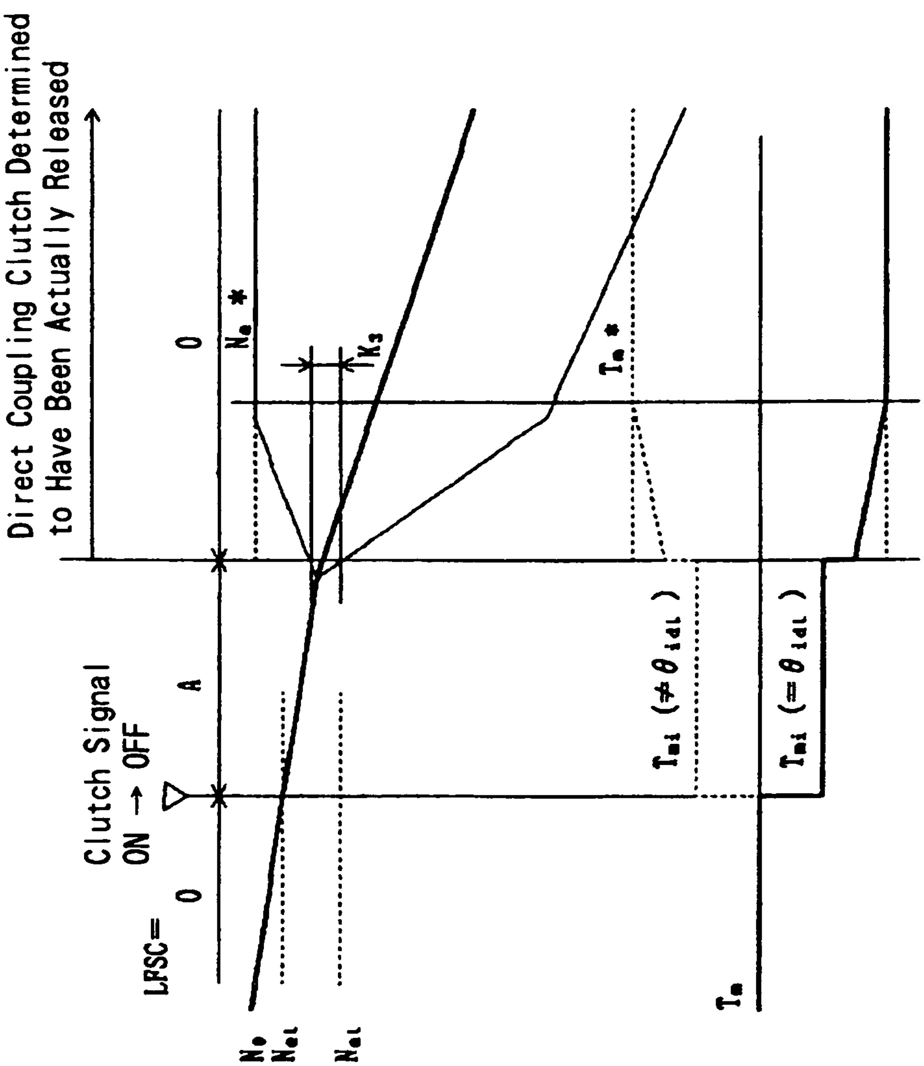

Direct Coupling Clutch Release Control Process Subroutine START
S11-1
LFSC=0
Y
N
S11-2
Fuel Cutoff or Regeneration Control
S11-3
Setting of N_{el}'
S11-4
$N_e < N_{el}$
Y
N
S11-5
Clutch Signal OFF
S11-6
L IF S C = A
S11-7
Setting of Initial Torque
S11-8
LFSC=A
Y
N
S11-9
$|N_e - N_o| > K_3$
Y
N
S11-10
L F S C = 0
S11-11
Resetting of Initial Torque
RETURN

FIG. 11



Direct Coupling Clutch Determined to Have Been Actually Released
Clutch Signal ON → OFF
LFSC=
0
A
0
N_e
N_{et}
N_{et}
N_e *
K_3
T_m *
T_{mi} ($\neq \theta_{idl}$)
T_{mi} ($= \theta_{idl}$)
T_m

FIG. 12

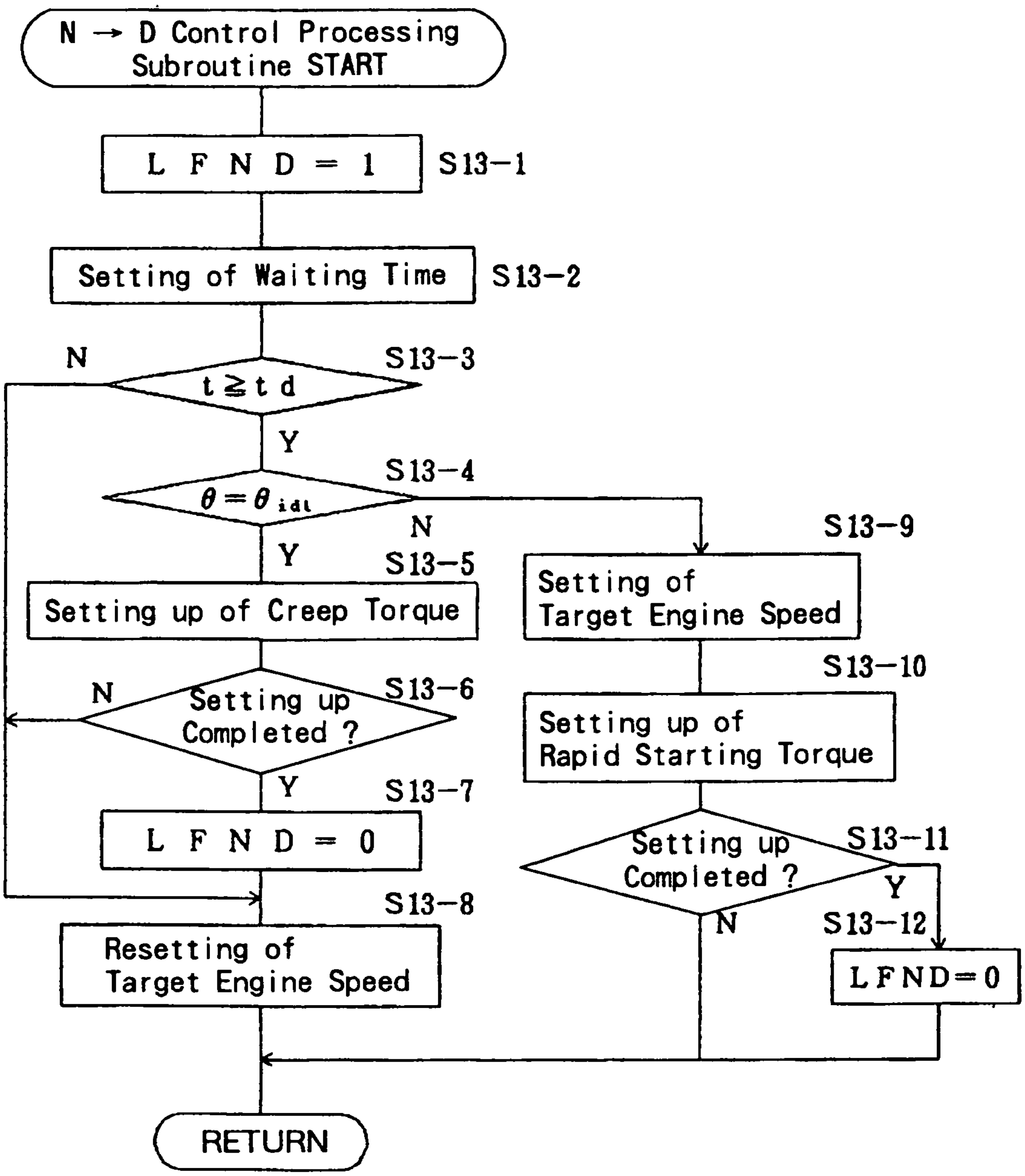

N → D Control Processing Subroutine START
L F N D = 1
S13-1
Setting of Waiting Time
S13-2
N
S13-3
t ≧ t d
Y
S13-4
θ = θ idl
N
S13-9
Y
S13-5
Setting up of Creep Torque
Setting of Target Engine Speed
S13-10
N
Setting up Completed ?
S13-6
Setting up of Rapid Starting Torque
Y
S13-7
L F N D = 0
Setting up Completed ?
S13-11
Y
N
S13-8
S13-12
Resetting of Target Engine Speed
LFND=0
RETURN

FIG. 13

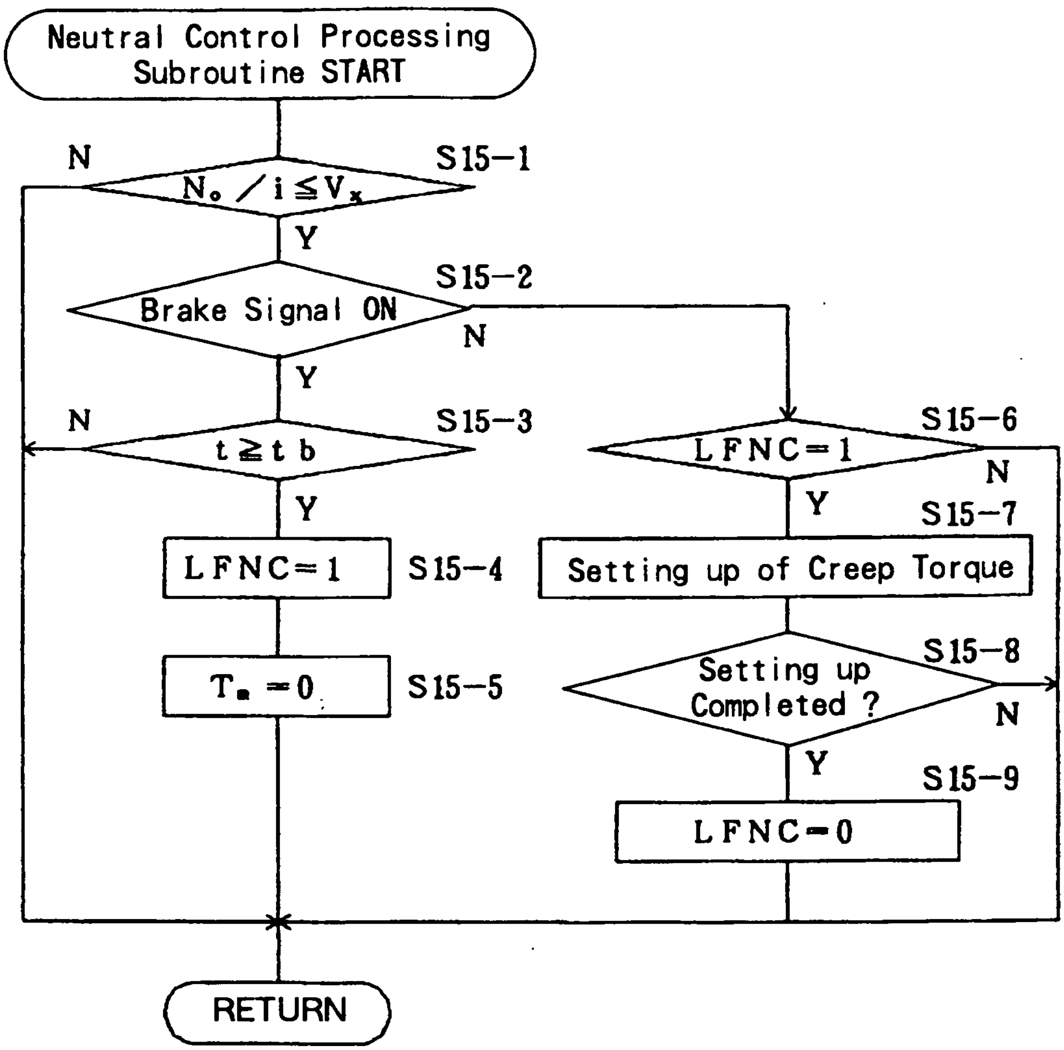

Neutral Control Processing Subroutine START
N
S15−1
$N_o / i \leq V_x$
Y
S15−2
Brake Signal ON
N
Y
N
S15−3
$t \geq tb$
Y
LFNC=1
S15−4
$T_m = 0$
S15−5
S15−6
LFNC=1
N
Y
S15−7
Setting up of Creep Torque
S15−8
Setting up Completed ?
N
Y
S15−9
LFNC=0
RETURN

FIG. 14

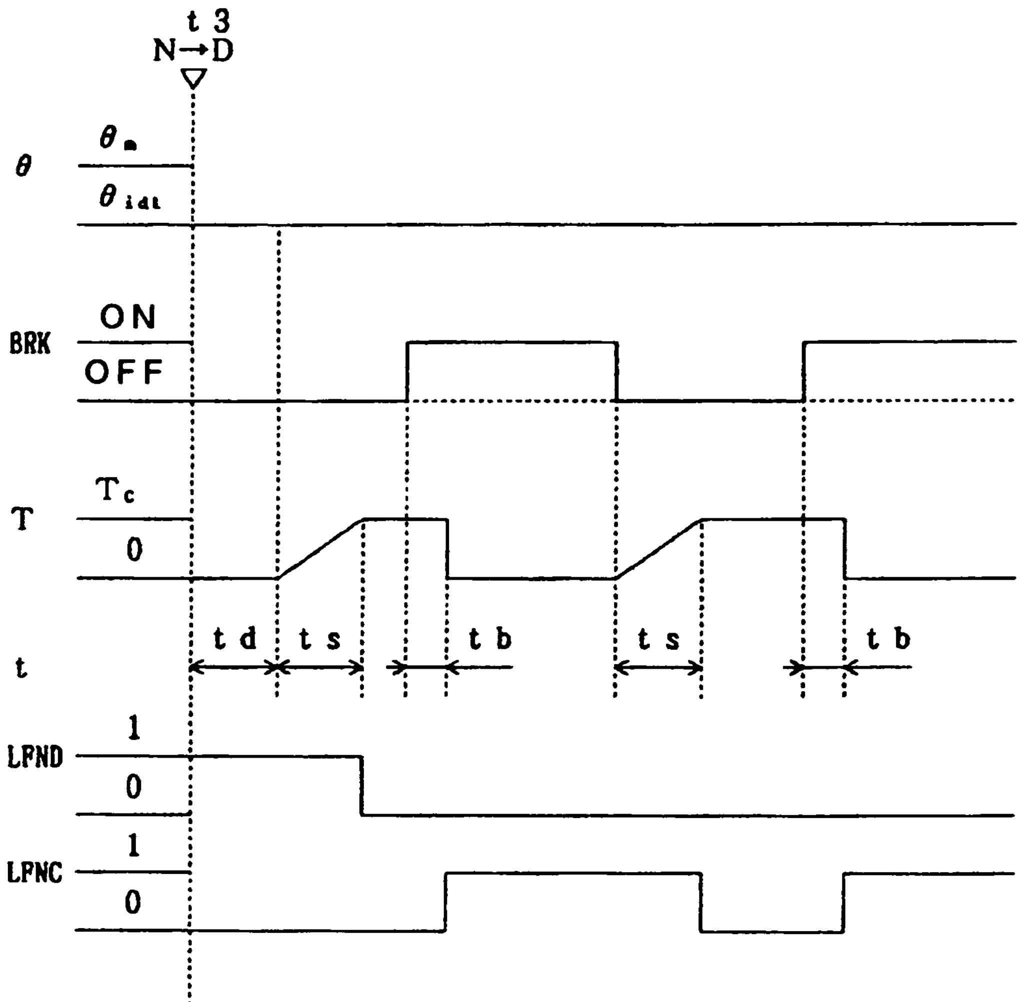


FIG. 15

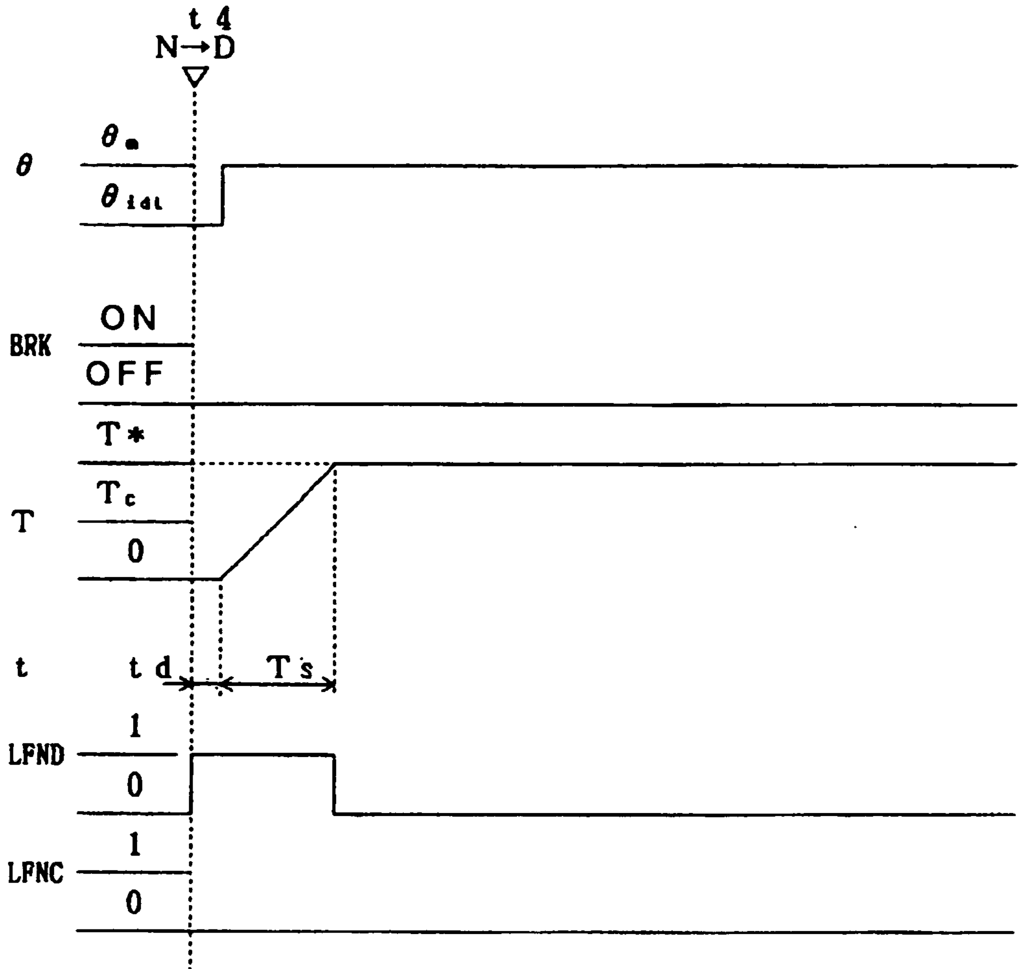


FIG. 16

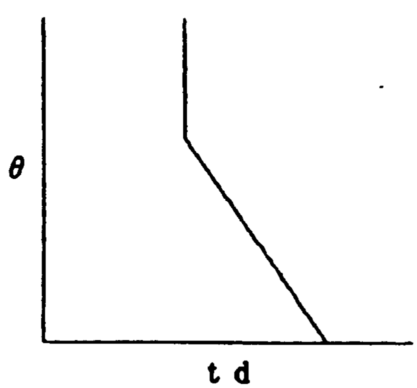


FIG. 17

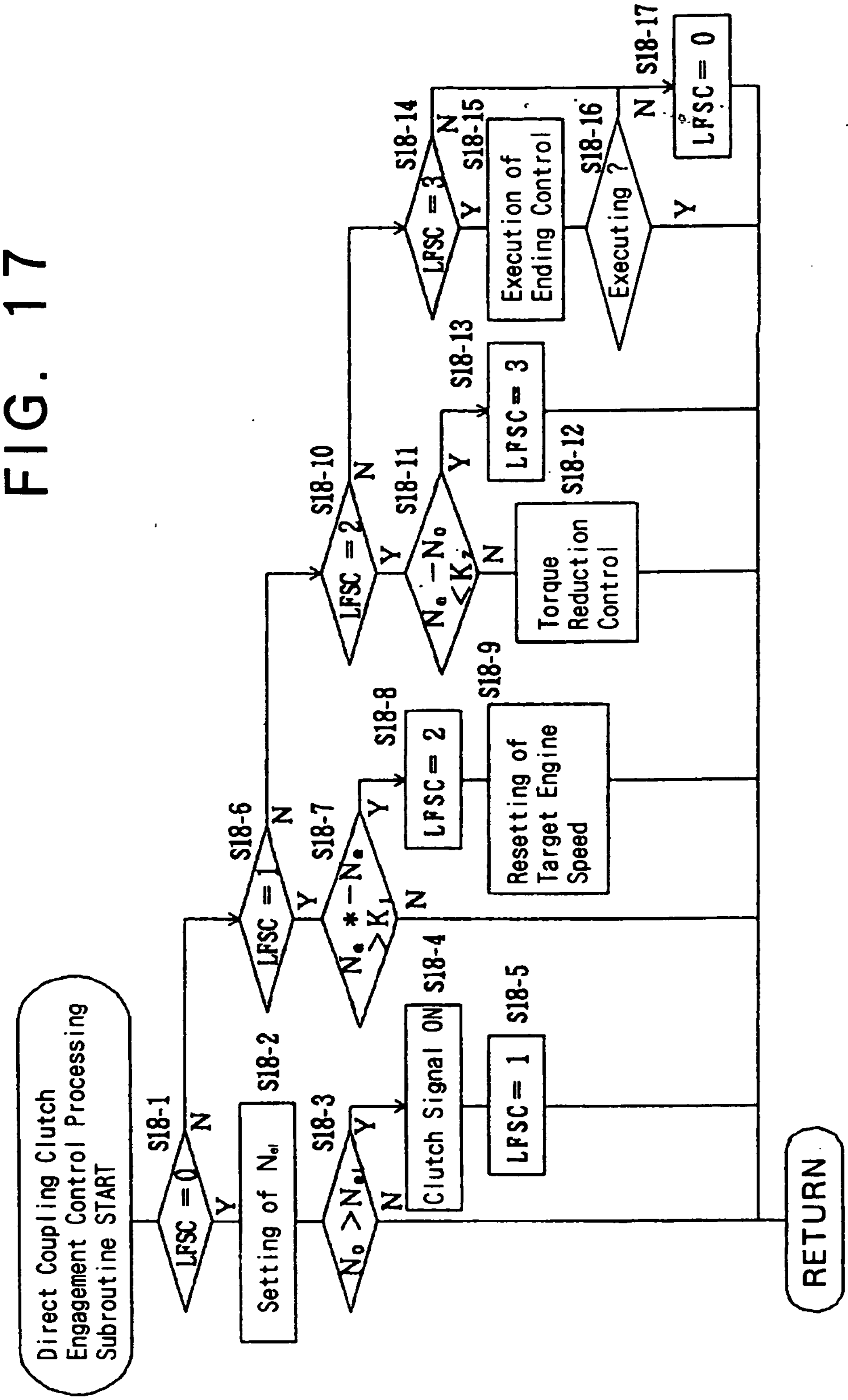

Direct Coupling Clutch Engagement Control Processing Subroutine START
S18-1
LFSC = 0
Y
N
S18-2
Setting of N_{e1}
S18-3
$N_o > N_{e1}$
Y
N
S18-4
Clutch Signal ON
S18-5
LFSC= 1
S18-6
LFSC = 1
Y
N
S18-7
$N_e * - N_e > K_1$
Y
N
S18-8
LFSC= 2
S18-9
Resetting of Target Engine Speed
S18-10
LFSC = 2
Y
N
S18-11
$N_e - N_o < K_2$
Y
N
S18-12
Torque Reduction Control
S18-13
LFSC= 3
S18-14
LFSC = 3
Y
N
S18-15
Execution of Ending Control
S18-16
Executing ?
Y
N
S18-17
LFSC= 0
RETURN

FIG. 18

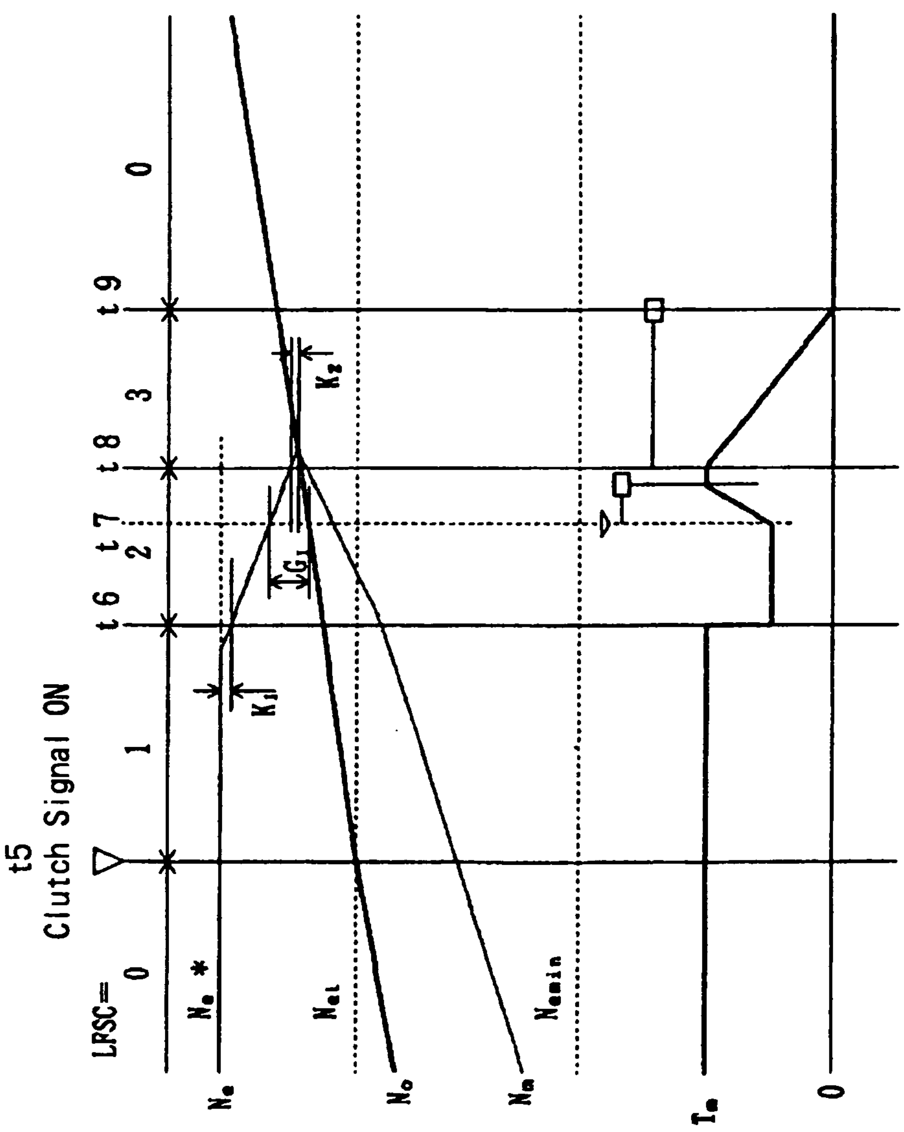

t5
Clutch Signal ON
LFSC=
0
1
2
3
0
t6
t7
t8
t9
Ne *
Nel
Nemin
Ne
No
Nm
Tm
0
K1
G1
K2

FIG. 19

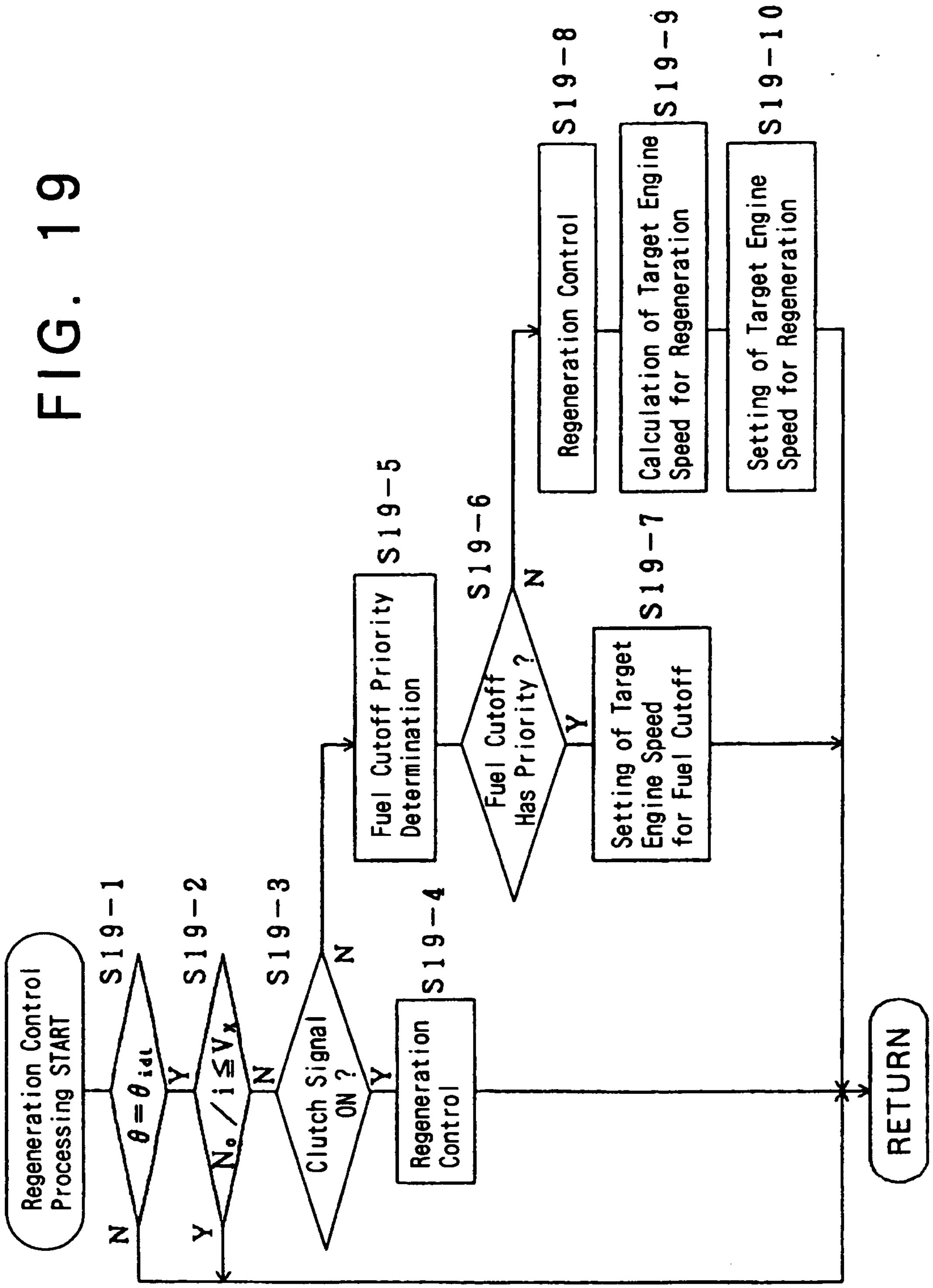

Regeneration Control Processing START
S19-1
$\theta = \theta_{idl}$
N
Y
S19-2
$N_o / i \leq V_x$
Y
N
S19-3
Clutch Signal ON ?
Y
N
S19-4
Regeneration Control
S19-5
Fuel Cutoff Priority Determination
S19-6
Fuel Cutoff Has Priority ?
Y
N
S19-7
Setting of Target Engine Speed for Fuel Cutoff
S19-8
Regeneration Control
S19-9
Calculation of Target Engine Speed for Regeneration
S19-10
Setting of Target Engine Speed for Regeneration
RETURN

FIG. 20

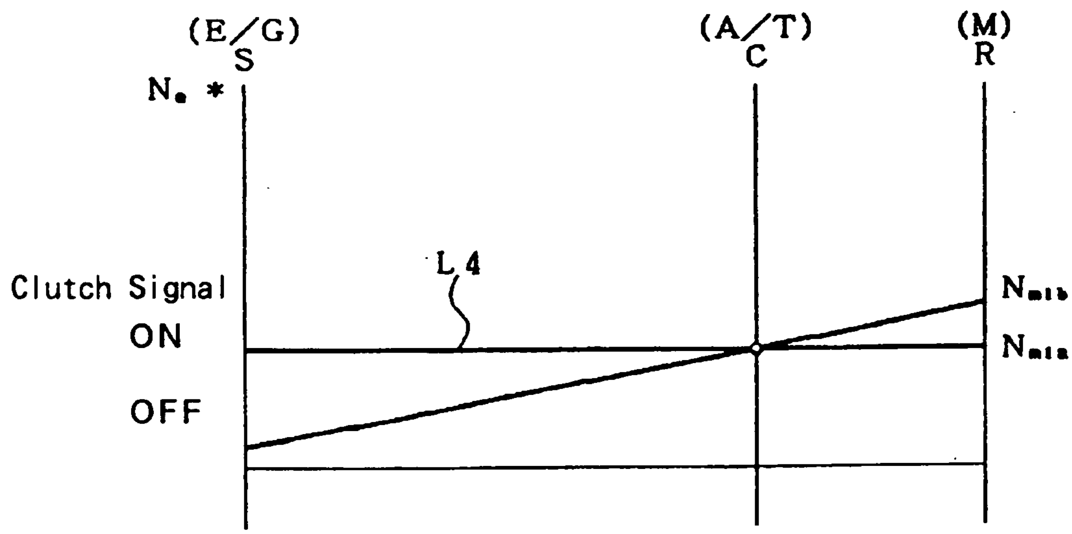


FIG. 21

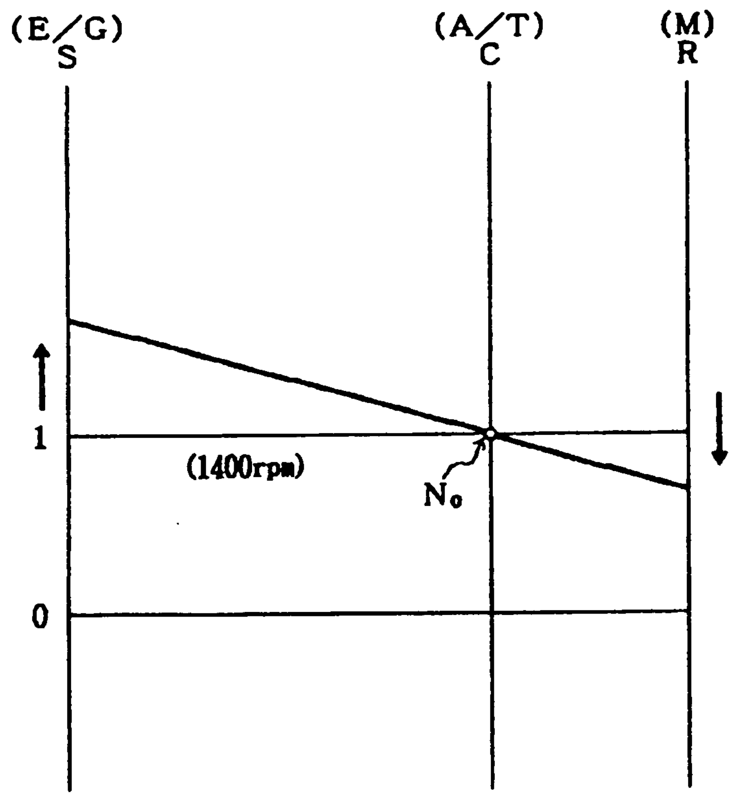


FIG. 22

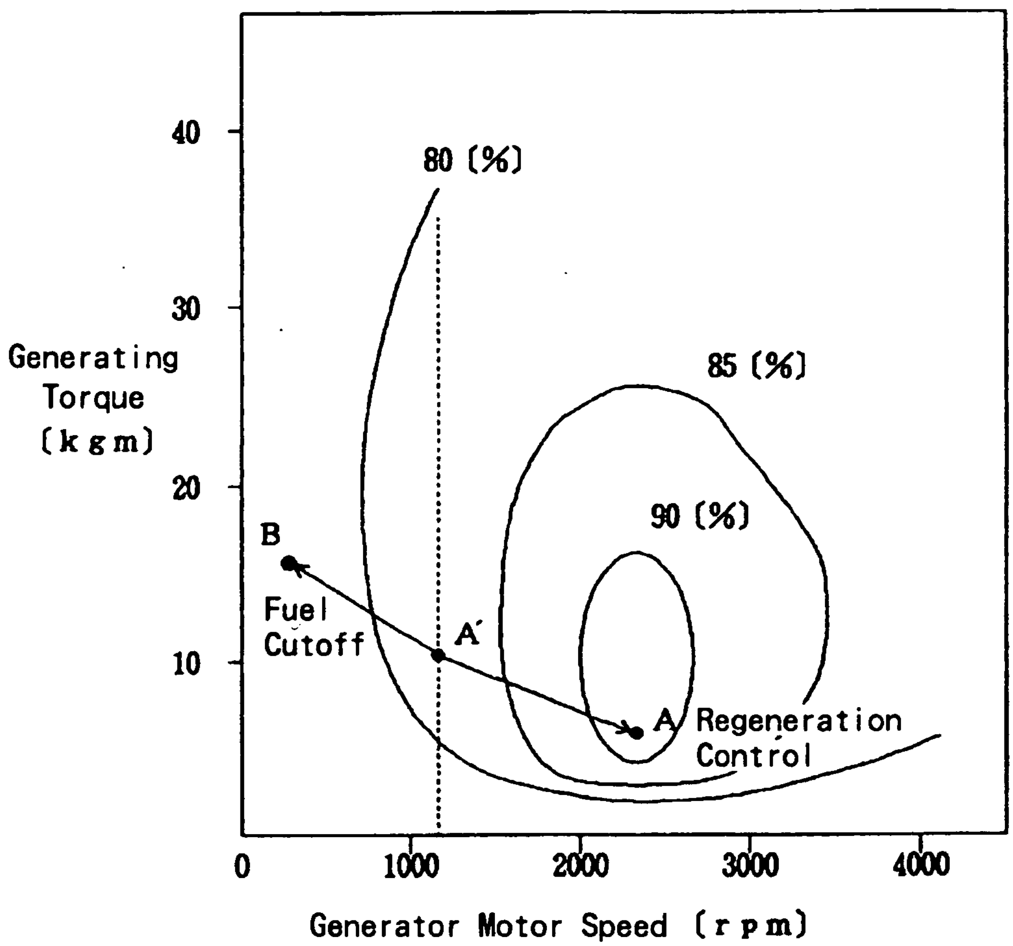

40
30
20
10
Generating
Torque
(kgm)
80 (%)
85 (%)
90 (%)
B
Fuel
Cutoff
A'
A
Regeneration
Control
0
1000
2000
3000
4000
Generator Motor Speed (rpm)

FIG. 23

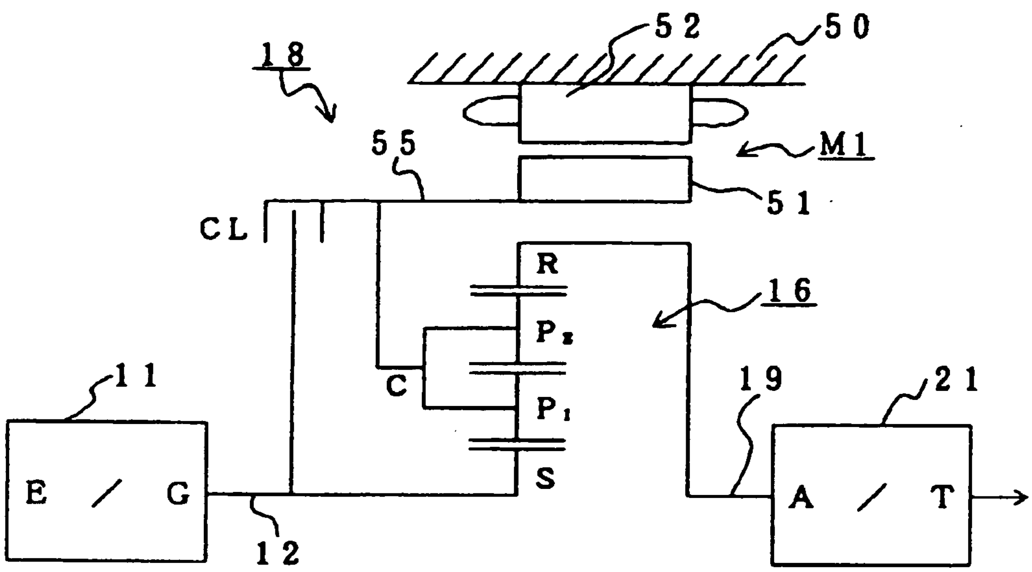

18
52
50
M1
55
51
CL
R
16
P2
C
P1
11
19
21
S
E / G
A / T
12

FIG. 24

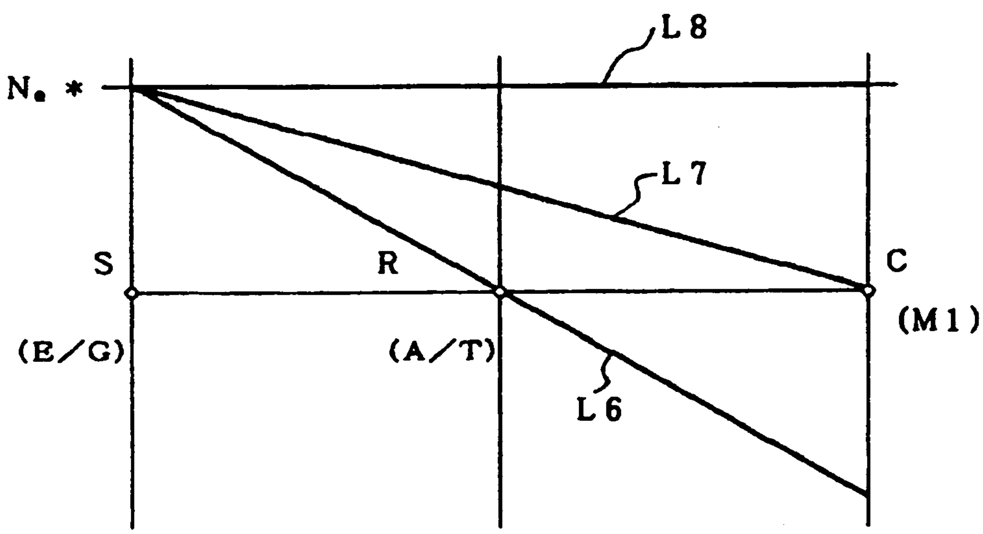

L8
Ne *
L7
S
R
C
(E/G)
(A/T)
(M1)
L6

FIG. 25

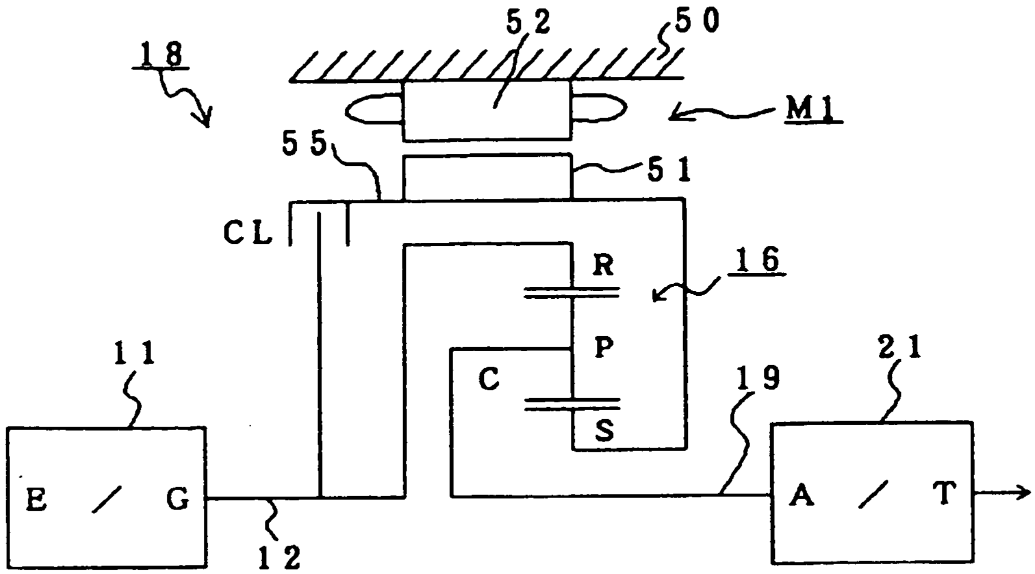

52
50
18
M1
55
51
CL
R
16
P
11
C
19
21
S
E / G
A / T
12

FIG. 26

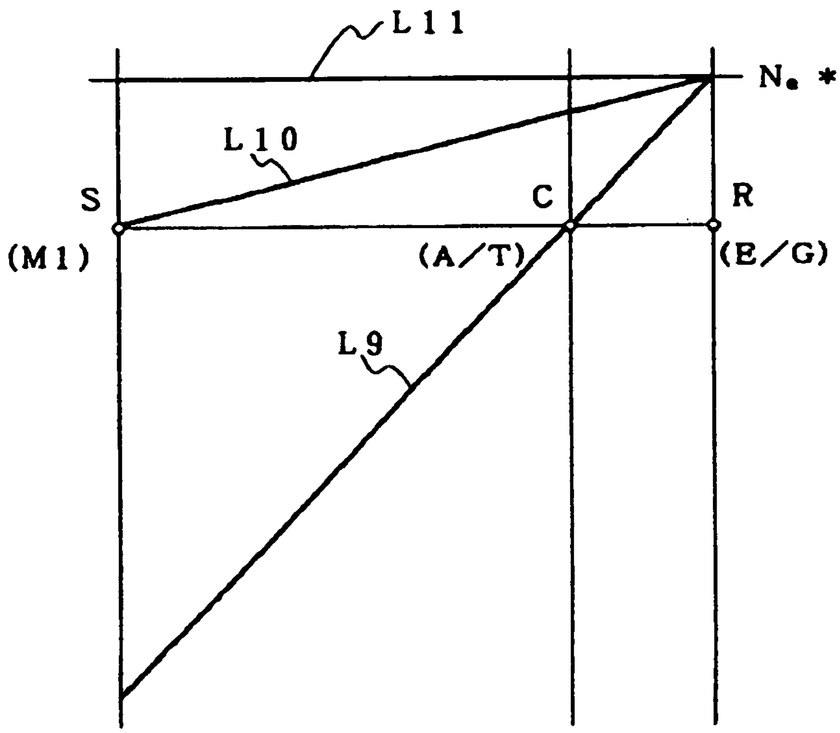

L11
N_e *
L10
S
C
R
(M1)
(A/T)
(E/G)
L9

FIG. 27

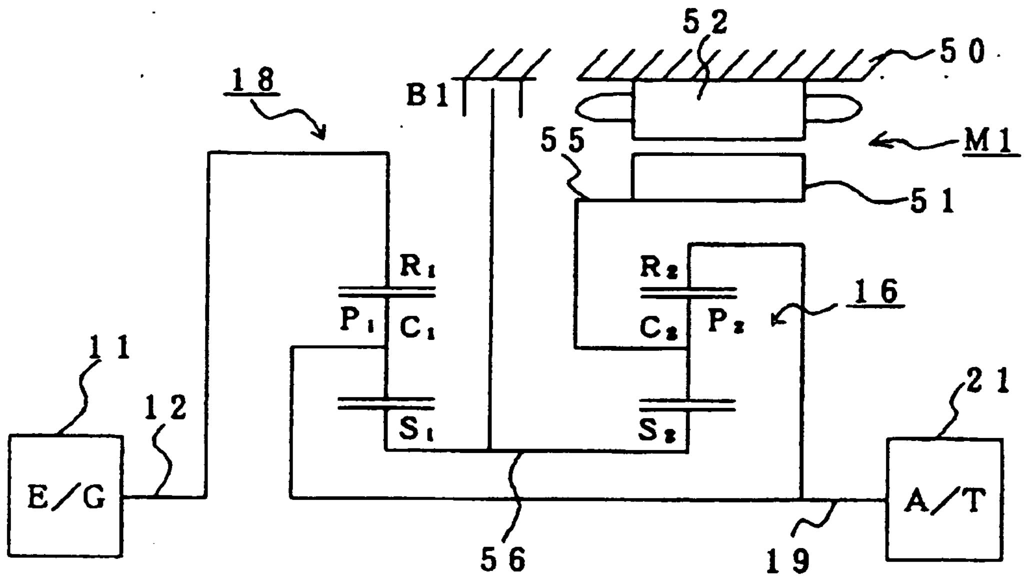

52
50
18
B1
55
M1
51
R1
R2
16
P1
C1
C2
P2
11
21
12
S1
S2
E/G
A/T
56
19

FIG. 28

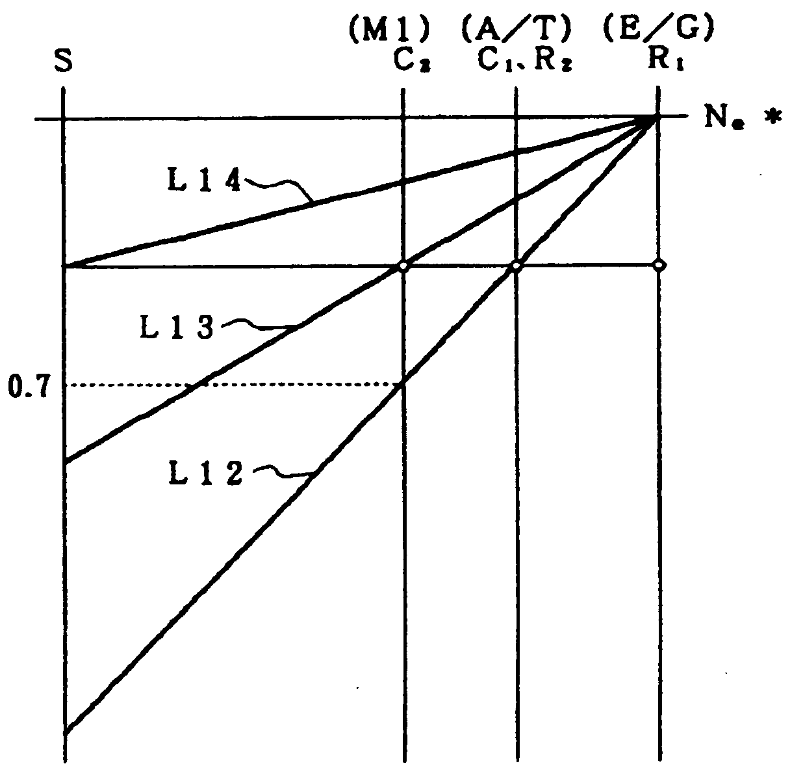

(M1)
(A/T)
(E/G)
S
C2
C1, R2
R1
Ne *
L14
L13
0.7
L12

FIG. 29

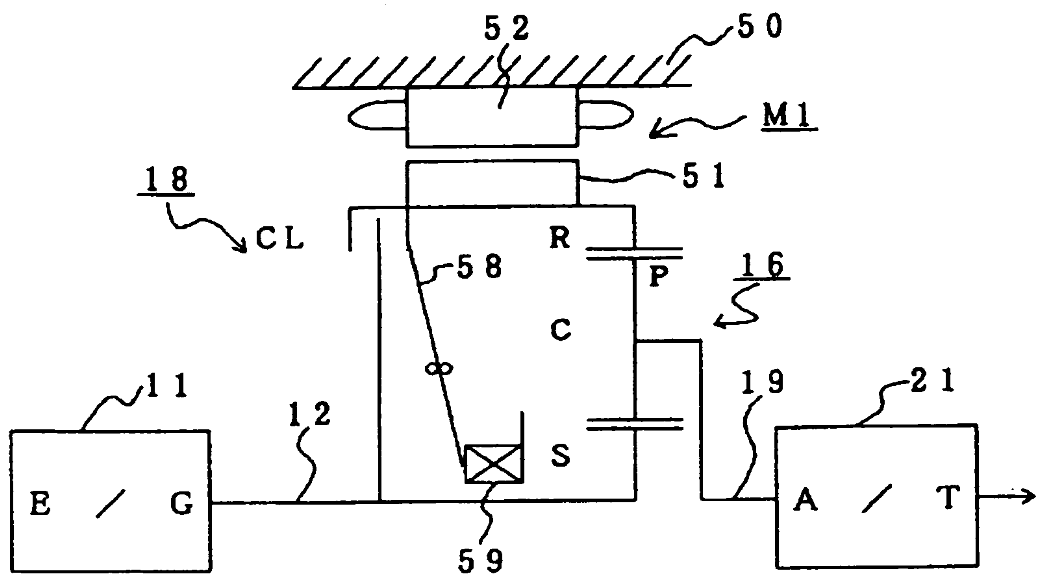


FIG. 30

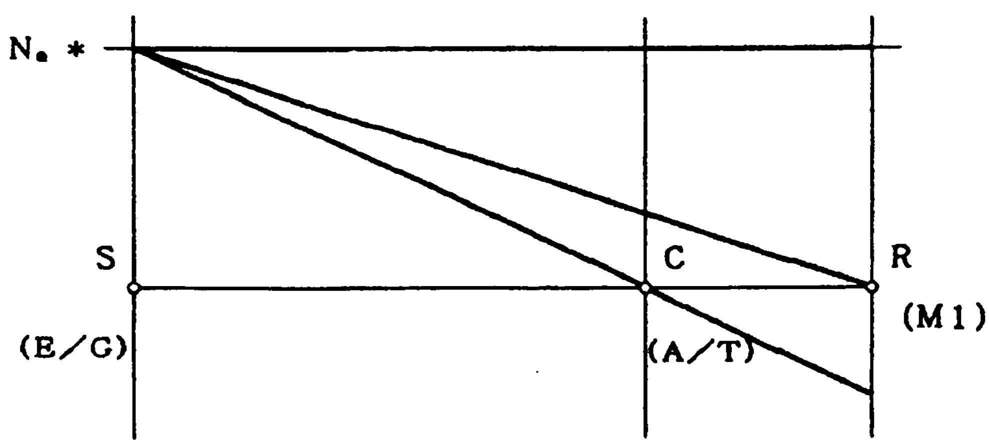


FIG. 31

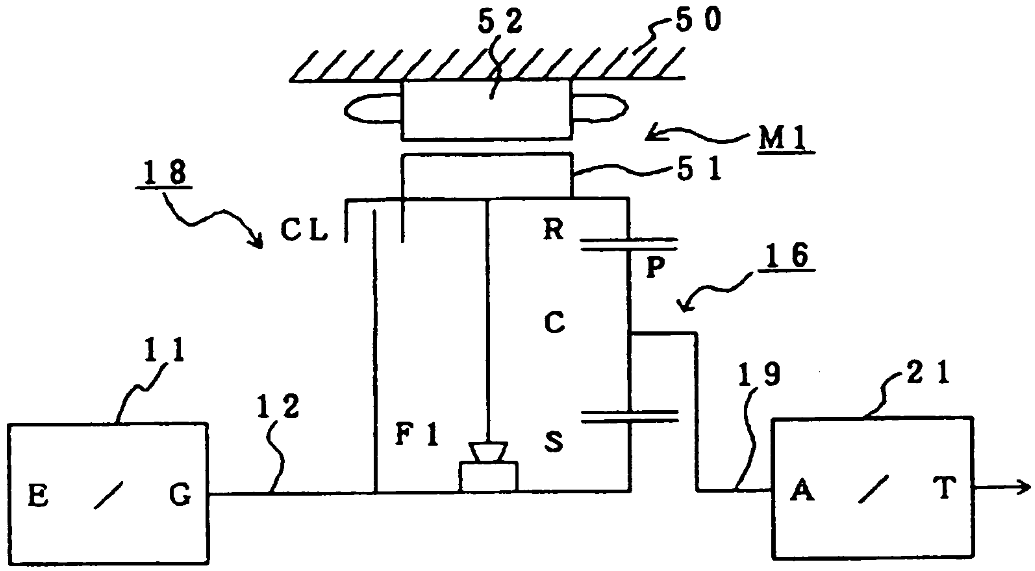


FIG. 32

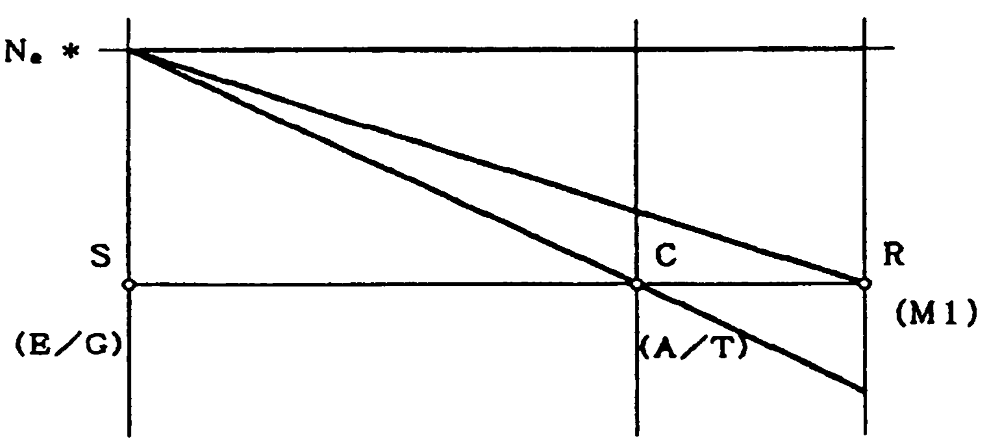
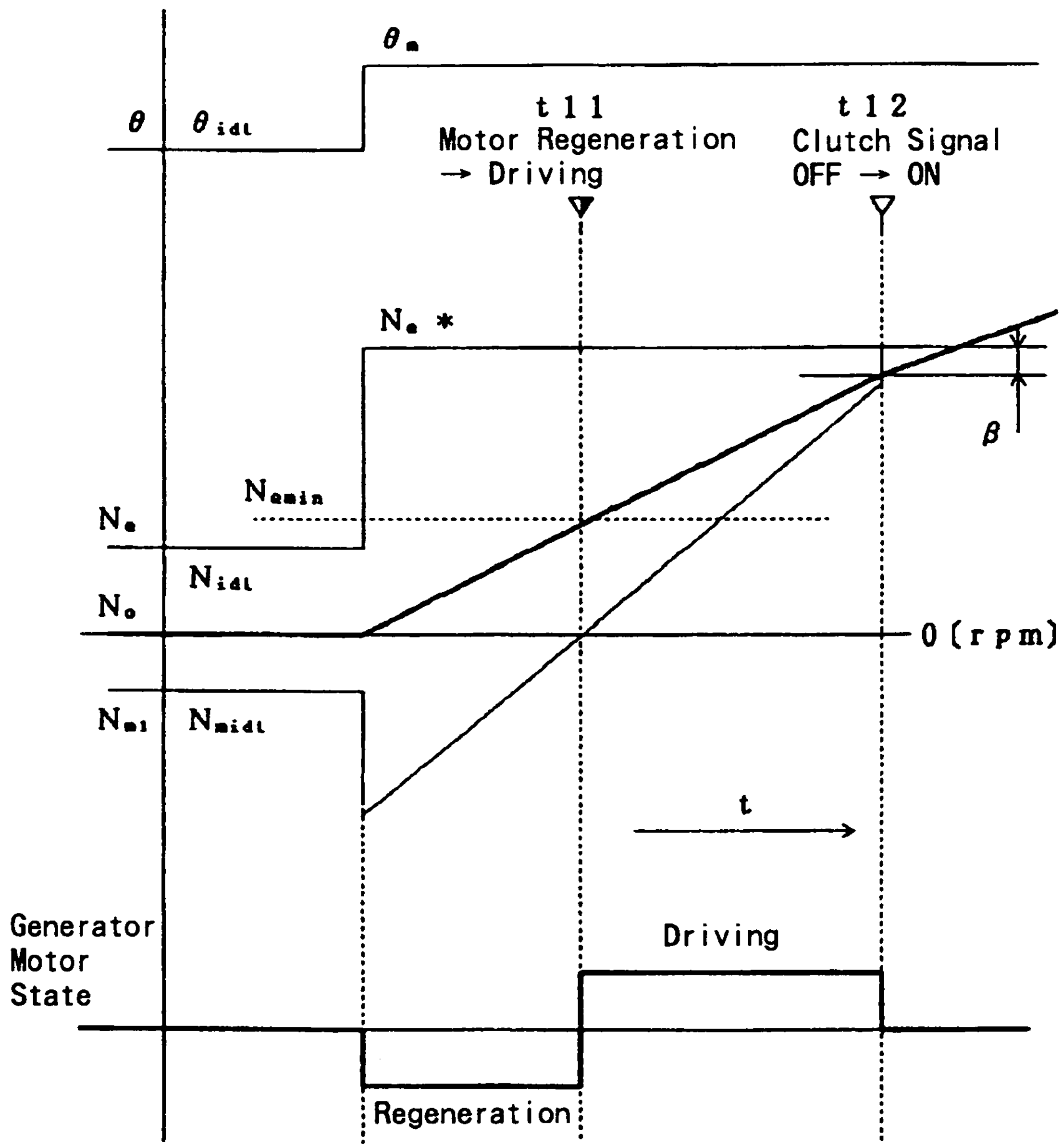


FIG. 33



θm
θ
θidl
t11
Motor Regeneration
→ Driving
t12
Clutch Signal
OFF → ON
Ne *
β
Nemin
Ne
Nidl
No
0 (rpm)
Nm1
Nmidl
t
Generator
Motor
State
Driving
Regeneration

FIG. 34

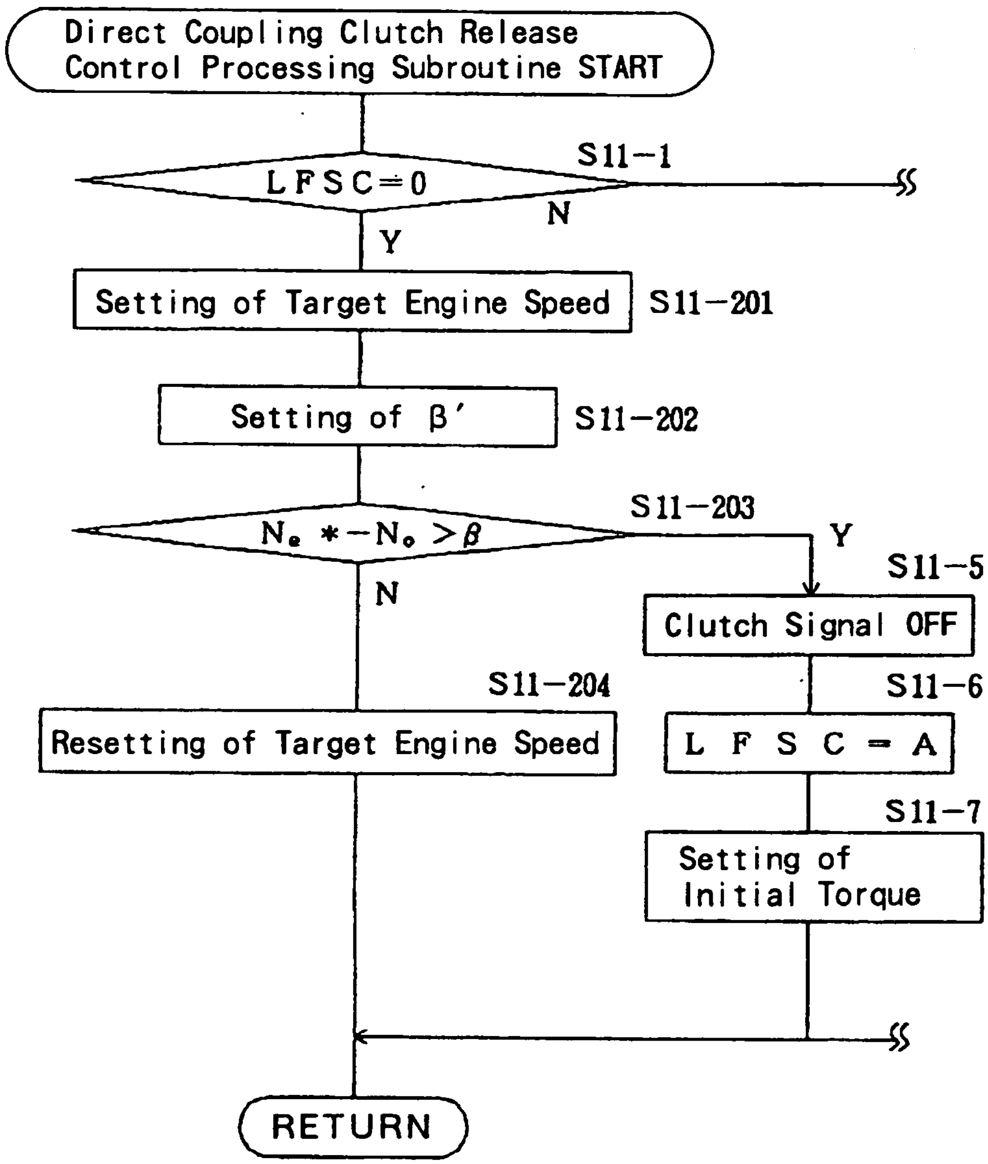

Direct Coupling Clutch Release
Control Processing Subroutine START
LFSC=0
S11-1
N
Y
Setting of Target Engine Speed
S11-201
Setting of β'
S11-202
Ne *-No >β
S11-203
Y
S11-5
N
Clutch Signal OFF
S11-204
S11-6
Resetting of Target Engine Speed
L F S C = A
S11-7
Setting of
Initial Torque
RETURN

FIG. 35

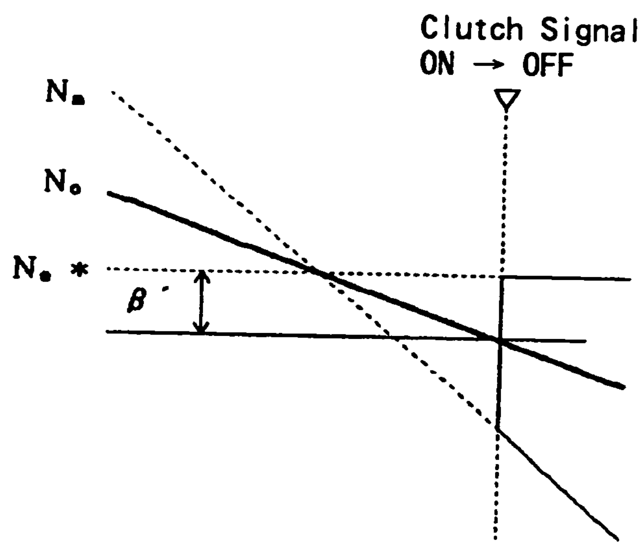

Clutch Signal
ON → OFF
N_m
N_o
N_e *
β'

FIG. 36

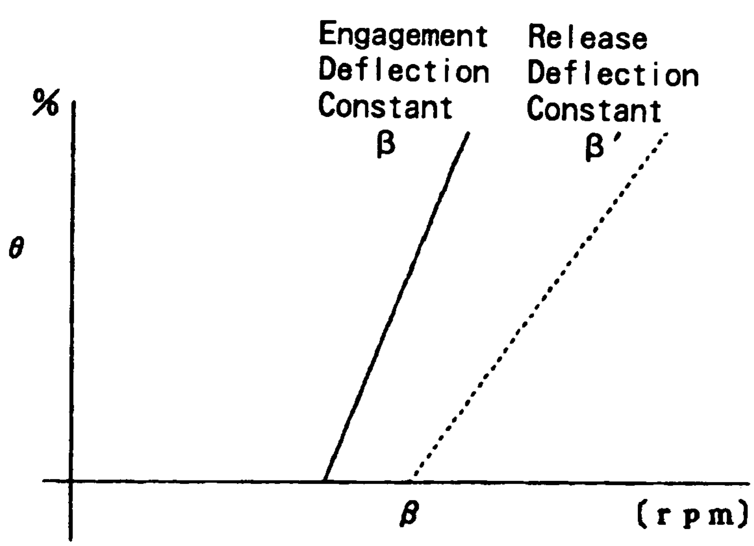

Engagement
Deflection
Constant
β
Release
Deflection
Constant
β'
%
θ
β
(rpm)

FIG. 37

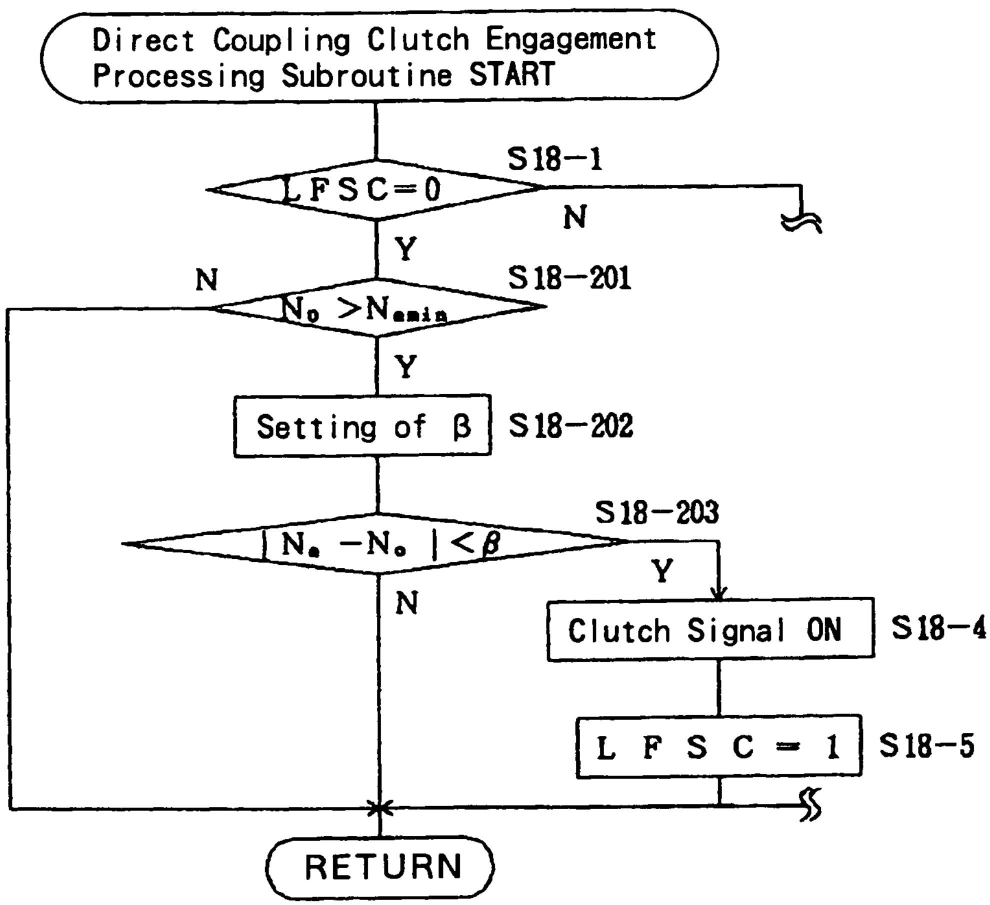
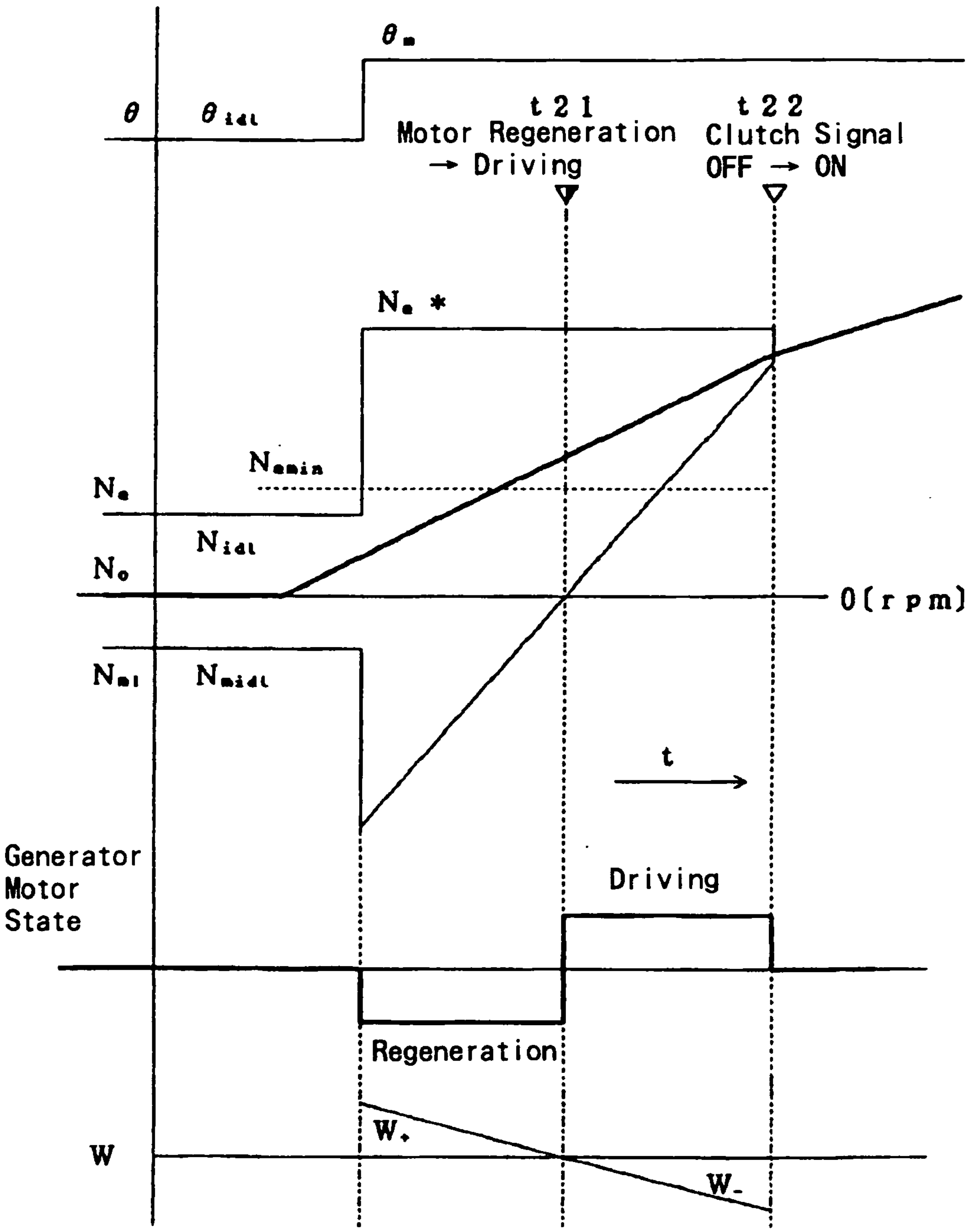

Direct Coupling Clutch Engagement Processing Subroutine START
S18-1
LFSC=0
N
Y
N
S18-201
$N_0 > N_{emin}$
Y
Setting of β
S18-202
S18-203
$|N_e - N_o| < \beta$
Y
N
Clutch Signal ON
S18-4
L F S C = 1
S18-5
RETURN

FIG. 38



θm
θ
θidl
t21
Motor Regeneration
→ Driving
t22
Clutch Signal
OFF → ON
Ne *
Nemin
Ne
Nidl
No
0 [rpm]
Nm1
Nmidl
t
Generator
Motor
State
Driving
Regeneration
W
W+
W-

FIG. 39

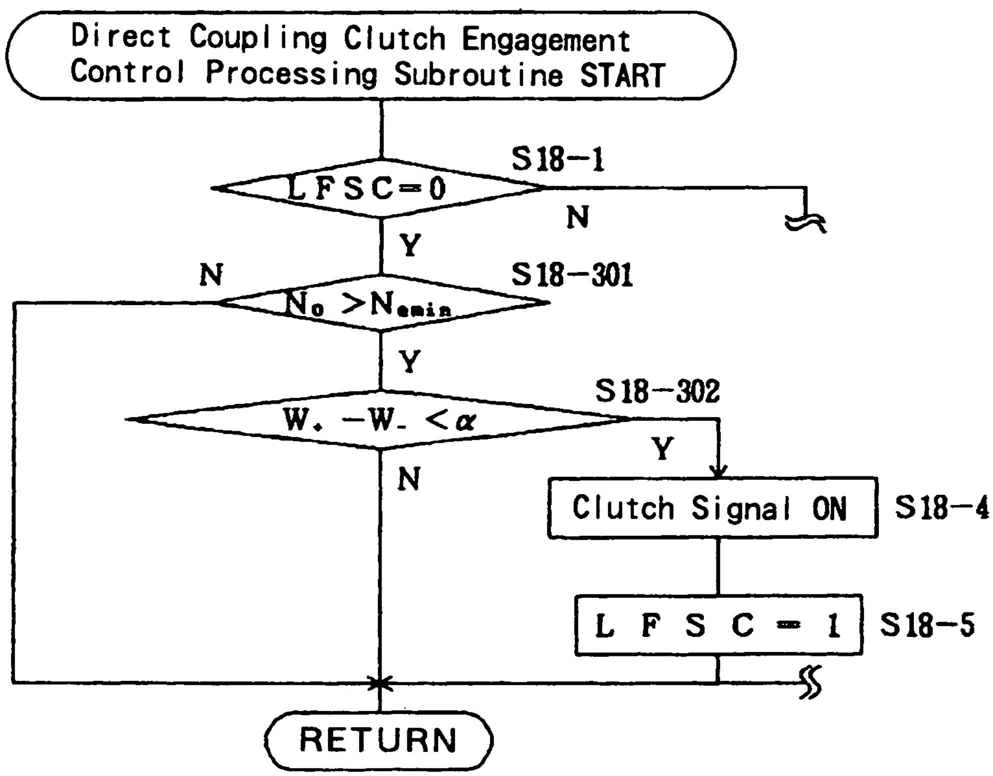

Direct Coupling Clutch Engagement Control Processing Subroutine START
LFSC=0
S18-1
N
Y
N
$N_0 > N_{emin}$
S18-301
Y
$W_+ - W_- < \alpha$
S18-302
Y
N
Clutch Signal ON
S18-4
L F S C = 1
S18-5
RETURN

FIG. 40

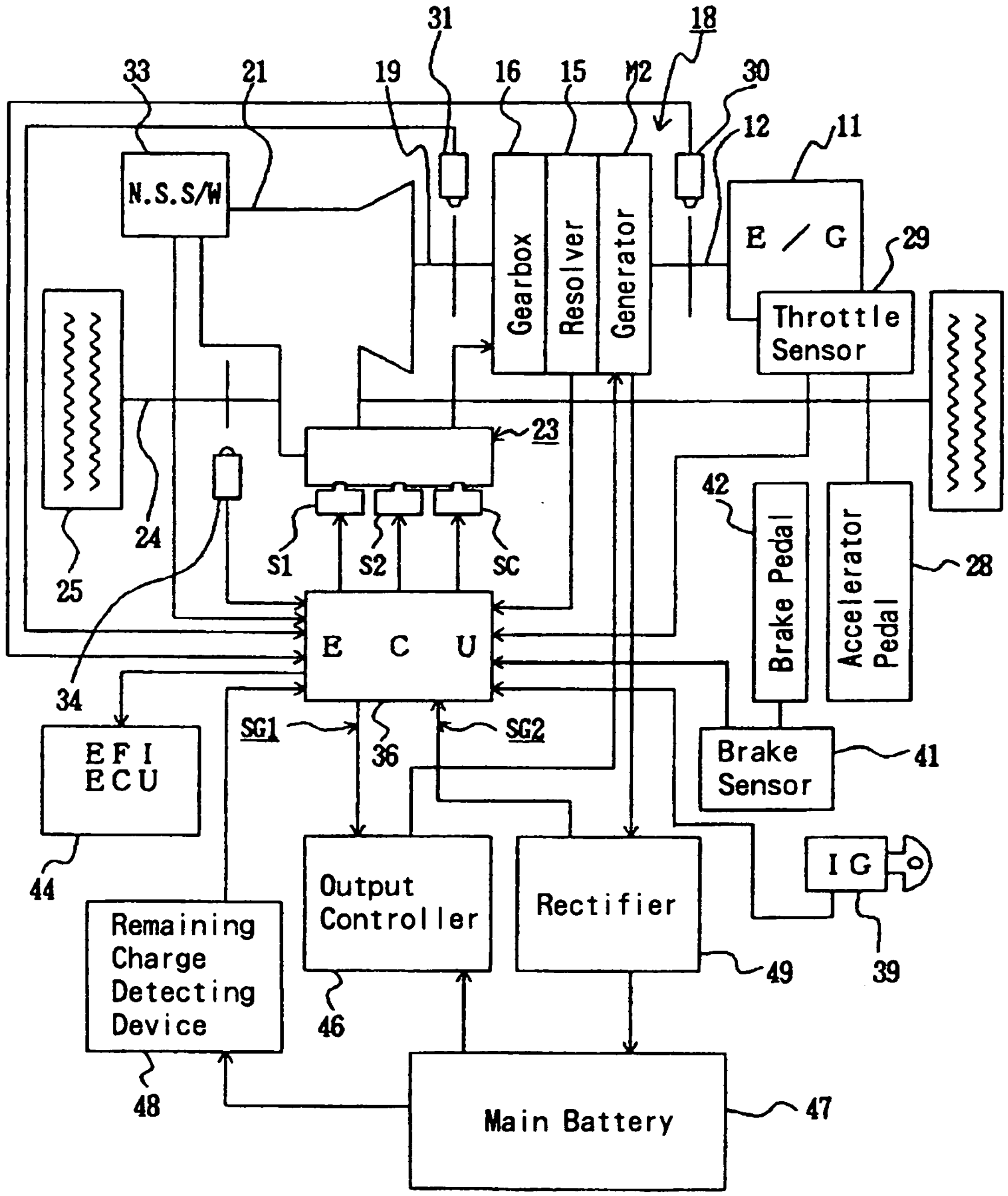
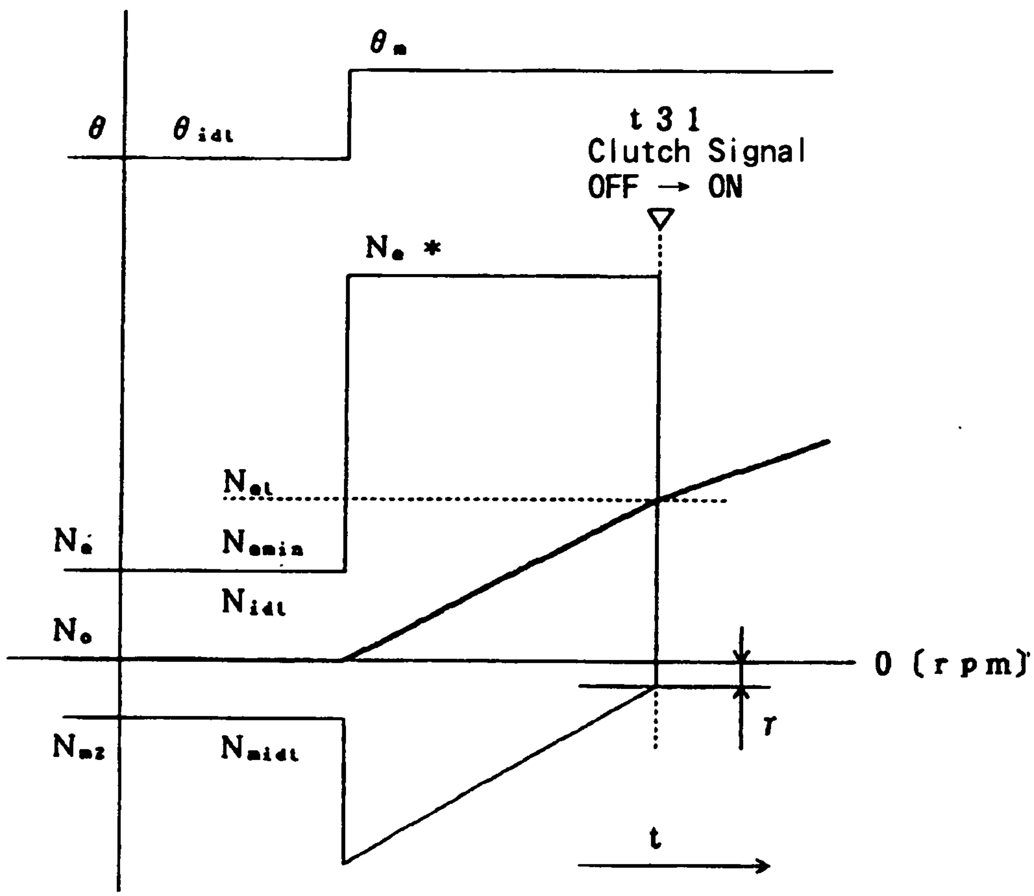

31
18
33
21
19
16
15
M2
30
12
11
N.S.S/W
Gearbox
Resolver
Generator
E / G
29
Throttle Sensor
23
42
Brake Pedal
Accelerator Pedal
28
25
24
S1
S2
SC
E C U
34
EFI ECU
SG1
36
SG2
Brake Sensor
41
44
Output Controller
Rectifier
IG
Remaining Charge Detecting Device
49
39
46
48
Main Battery
47

FIG. 41



θ
θidl
θm
t31
Clutch Signal
OFF → ON
Ne *
Nel
Ne
Nemin
Nidl
No
0 (rpm)
Nm2
Nmidl
T
t

FIG. 42

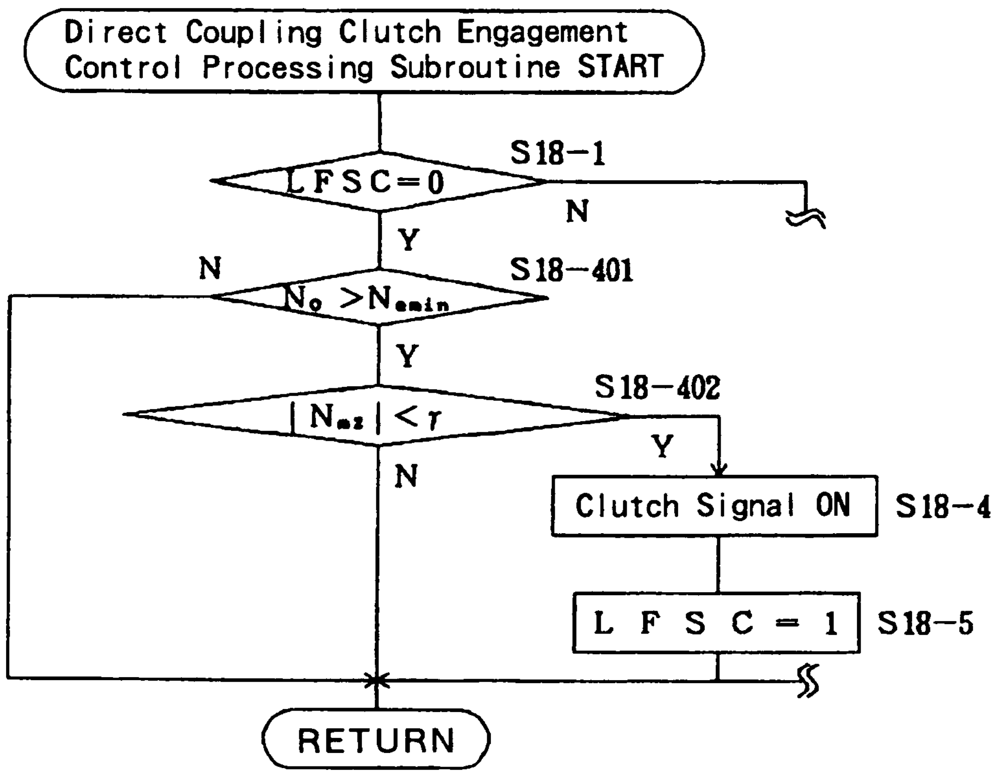

Direct Coupling Clutch Engagement Control Processing Subroutine START
S18-1
LFSC=0
N
Y
N
S18-401
$N_0 > N_{emin}$
Y
S18-402
$|N_{e2}| < \gamma$
Y
N
Clutch Signal ON
S18-4
LFSC = 1
S18-5
RETURN

FIG. 43

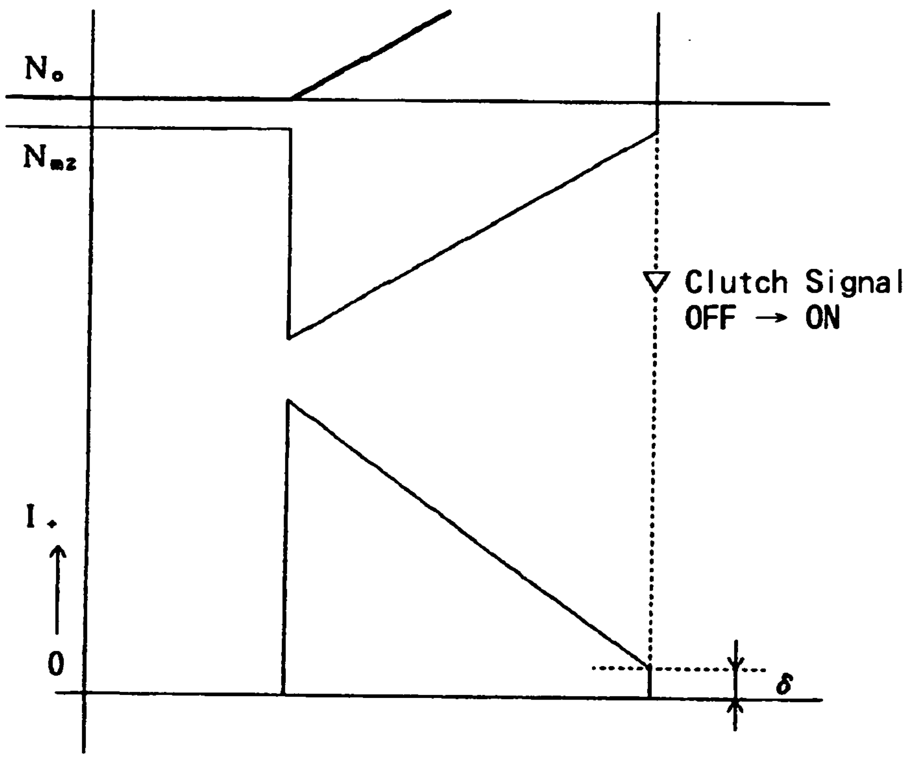


FIG. 44

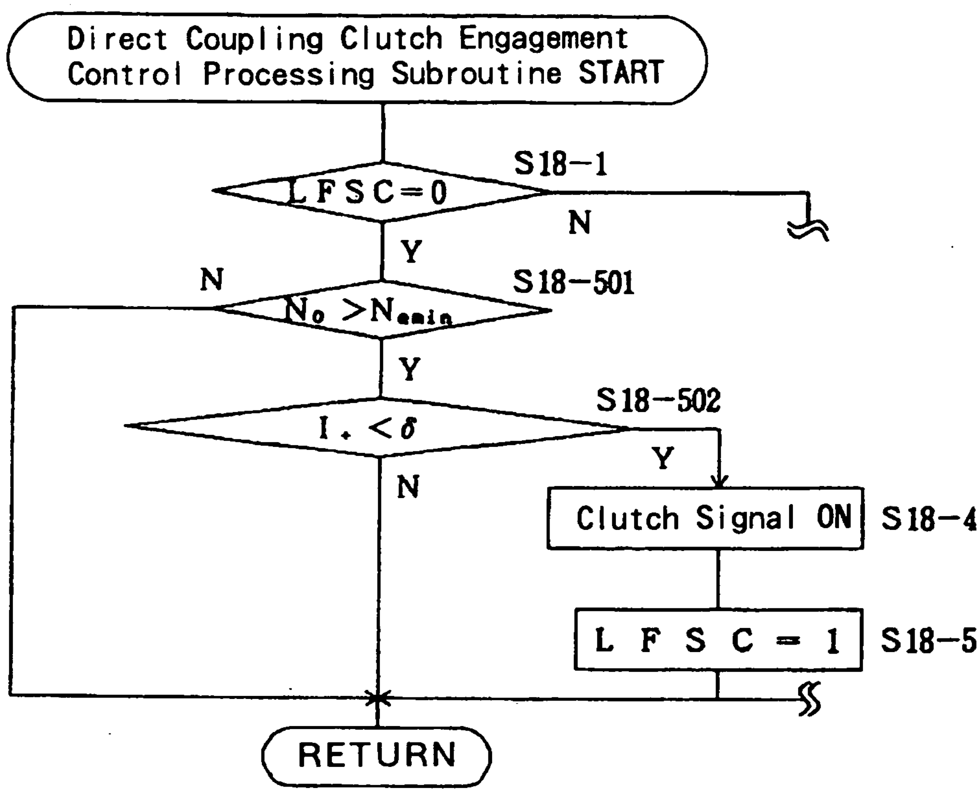
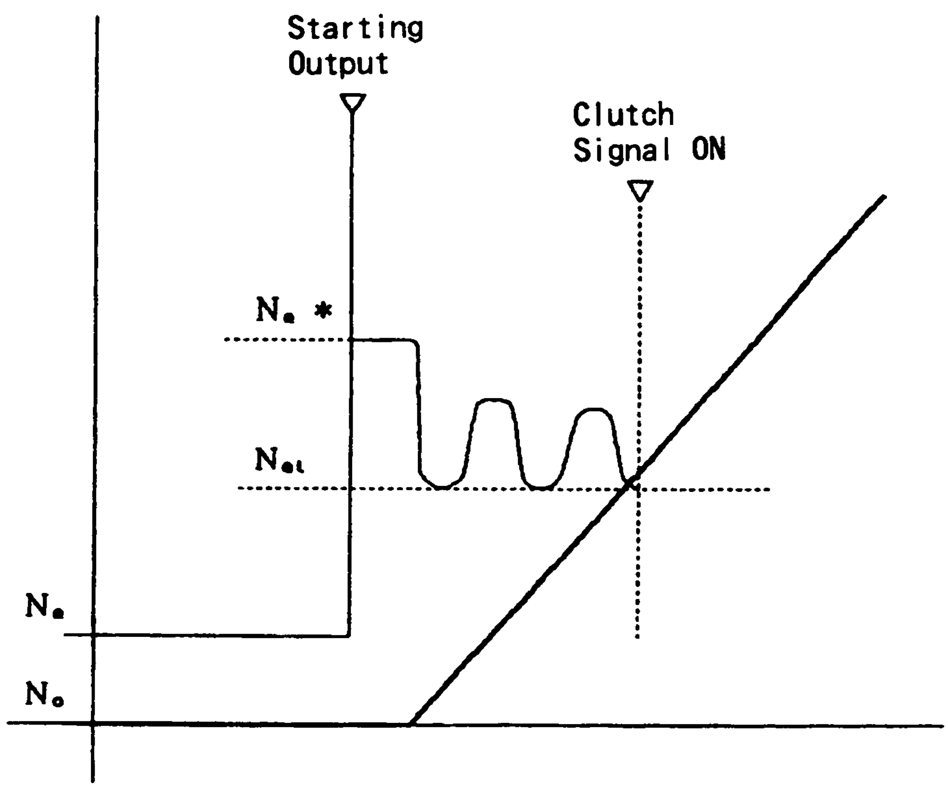

Direct Coupling Clutch Engagement Control Processing Subroutine START
LFSC=0
S18-1
N
Y
N
S18-501
No >Nemin
Y
S18-502
I+ <δ
Y
N
Clutch Signal ON
S18-4
L F S C = 1
S18-5
RETURN

FIG. 45



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